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CONTROLS ON AND USES OF

HYDROCHEMICAL AND ISOTOPIC HETEROGENEITY

IN THE

PLATEAU AQUIFER SYSTEM, CONTIGUOUS AQUIFERS,

AND

ASSOCIATED SURFACE WATER,

EDWARDS PLATEAU REGION, TEXAS

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by

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Dedication

To Jean, faithful and true, steadfast in the face of the challenges presented by travelling with me across life. You have been there for every turn. Almost every thing of real value to me we have done together. Thank you for being there.

Acknowledgements

The members of my committee, Jack Sharp, Jay Banner, Charlie Kerans, Bridget Scanlon, Eric James, and Robert Mace were profoundly instrumental in providing essential components to pursuing and completing this dissertation. Thanks also to Alan Dutton who, as a supervisor of my first environmental project at the Bureau and as a member of my Examining Committee, provided support at an early period in my present educational campaign. Randy Merrett, also on my Examining Committee, offered some valuable insights to me on the approach to Ph.D.-level research. Their consent to serve on my committees is appreciated and indispensible. Every one of these fine people has contributed to my professional growth. Some have been directly interested in my techniques and findings, while others saw value in encouraging me to find my own way. I have benefitted from both approaches. In some cases the most valuable influence from any particular member may have been during a period in my career that preceded undertaking this project, although they may not appreciate to what particular influence I am referring.

I owe special thanks to the Texas Water Development Board for funding the laboratory analyses of samples that I collected during the course of this study. Special thanks to Janie Hopkins and Chris Muller of the Board for their personal assistance, and to Robert Mace who, recognizing the potential contributions to water resource management that would be served by my efforts, facilitated acquisition of TWDB funding for the analyses required by my project. The Geology Foundation also provided

funds on occasion that helped defray the impact of personal costs attendant with field work. Doug Ratcliff, of long friendly professional acquaintance, was instrumental in the approval of Foundation contributions.

I also thank managers of staff of several groundwater conservation districts that gave my logistical needs during the sampling campaign their special attention. In many cases they arranged access to wells and actually accompanied me to the sites. It doesn't get any better than that. Trust me, when you arrive at a ranch out in the southern Crockett Co. wilderness on the U.S-Mexico boarder to ask a total stranger of superior size and conspicuous armament if you can mess with his well, it helps to have someone along that they recognize. I thank Dennis Clark (Crockett Co.), Greta Ramsdale and Virgil Polocek (Sutton Co.), Jon Cartwright (Schleicher Co.), Cindy Weatherby (Reagan Co.), and Ricky Harston (Glasscock Co.) for their personal attention. Thanks also to Lupe Renden, former manager of the Bureau's core repository in Midland, Texas who led me to the wells of his friends and family in Midland Co. which has no groundwater conservation district. Regrettably, Virgil Polocek passed away relatively soon after our sampling excursion across Sutton Co. The enthusiastic and kind man will be missed by all who knew him.

I owe the supervisory staff of the Bureau of Economic Geology a debt of gratitude for employment that extends back across most of the years since spring 1977. It is within the context of Bureau projects that I have learned many of the analytical approaches and tools that have served me in this dissertation which is, at least on the surface, generally unlike anything I have done for the Bureau. I have a special kind of appreciation for those

many here who have asked me over the last two years “when are you going to finish?” Ian Duncan, Associate Director, has been an appreciated intellectual resource and motivating figure for my research over the last several years. Other Bureau scientists instrumental in my progress include Steve Ruppel, who supervised my stratigraphic efforts in recent years, Robert Loucks, who never lets me forget that I have about everything left to do, and Scott Hamlin, who has tolerated numerous unannounced assaults on his attention.

I also owe a brigade of medical doctors and staff too numerous to name a debt for their interventions over the last decade in a series of inconvenient escapades into medical pathology. Among these, Rebecca Clearman, M.D., of Houston ,Texas and David Decker, her husband and go-to guy for every kind of technical support for their medical enterprise, deserves special mention for navigating wife Jean and I though the maze to and through M.D. Anderson Cancer Center in 2002, and for giving us a friendly place to stay while in that twilight zone.

We are all products of the successes and failures that went before, the people we met for better or worst, our good decisions and bad. I owe professors and teaching assistants going back over 40 years, and teachers and friends that went even before those. Many of them are gone now, hopefully to better places. If things have worked out for the best then I owe a debt to all, and, in some philosophies, even to those whose objectives were insensitive or contrary to my own.

Thanks to all.

CONTROLS ON AND USES OF HYDROCHEMICAL AND ISOTOPIC HETEROGENEITY IN THE PLATEAU AQUIFER SYSTEM, CONTIGUOUS AQUIFERS, AND ASSOCIATED SURFACE WATER, EDWARDS PLATEAU REGION, TEXAS

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University of Texas at Austin, 2010

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ABSTRACT

Groundwater and surface water in the Edwards Plateau region exhibits spatial variability arising from mineral differences in aquifers and mixing of groundwaters with diverse flow paths and ages. Integration of basic hydrochemical and isotope data ($^{87}Sr/^{86}Sr$, $\delta^{18}O$, δD, ^{14}C, ^{3}H) document that groundwaters in the Lower Cretaceous Edwards-Trinity (Plateau) aquifer system reflect intermixing of modern and Pleistocene recharge. Pleistocene recharge occurred under cooler paleo-climatic conditions, based on $\delta^{18}O$ variance of 4.59‰, and flow traversed sub-cropping Permian evaporite and Triassic strata under hydraulic conditions that promoted upward flow into the Plateau system. Recharge areas may have been in topographically elevated areas in New Mexico that no longer are connected with the Plateau. Present distribution of groundwaters with higher SO_4/Cl values occurring beneath topographic divides on the Plateau suggests that modern

recharge occurs preferentially in losing-stream networks and is inhibited on divides by low-permeability soils.

Relationships between ^{14}C, tritium, $\delta^{13}C$, and Mg/Ca values confirm that effectively younger groundwaters occur beneath the upper parts of drainage networks, but down slope of divides. Thus, groundwater-age and hydrochemical data suggest that recharge preferentially occurs in the upper parts of drainage networks. Correlations between groundwater relative age and Mg/Ca enable estimation of the proportion of modern recharge at specific well locations based on Mg/Ca values and enables estimating local absolute recharge rates from regional-scale recharge estimates obtained from regional flow models.

The Upper Colorado River bounds the northern and northeastern margin of the Plateau system and shows systematic chemical evolution along its flow path, including decreasing salinity and increasing SO_4/Cl values. The stream can be conceptually divided into three segments that each reflect groundwater inputs from five hydrochemically distinct intervals: 1) deep Permian and Pennsylvanian reservoirs similar to those that produce hydrocarbons in the region; 2) Upper Permian halite (Salado Formation); 3) the Triassic siliciclastic aquifer (Dockum Group); 4) the sulfate-evaporite-bearing Permian system (Ochoan, Guadalupian, and Leonardian Series); and 5) the Plateau aquifer system. Conservative mixing models suggest that any aquifer that the river is traversing at a specific location contributes a distinct hydrochemical signature, but the dominant contribution is from the Plateau system.

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INTRODUCTION TO THE DISSERTATION

The Edwards Plateau is a largely semi-arid region in west-central and western Texas that includes one of the larger aquifer systems in the Southwest. The Edwards-Trinity (Plateau) aquifer system is composed of Cretaceous-aged siliciclastic and karsted carbonate strata that are in hydraulic contact with underlying Paleozoic and lower Mesozoic aquifers systems and with the overlying mammoth High Plains aquifer system. The lower part of the Plateau system, the Trinity aquifer, extends down topographic gradient into the Texas Hill Country where it contains an important groundwater resource. The average population of the 22 or so counties that occur at least partly on the Edwards Plateau is generally less than 4,000 people per county, with a few exceptions. The populations in these rural counties are concentrated near the county seats, however, where well fields abstract groundwater rather intensely from geographically limited areas. Although sparsely populated historically, the Plateau region is progressively being looked to for water supplies by growing municipalities that are present near its margins. Texas cities that increasingly depend on Plateau groundwater (in some cases, also on surface water originating largely in the Plateau system) include Midland, San Angelo, and Del Rio. Historic potentiometric maps indicate that water levels on the Plateau have fallen over the last 50 years and, if overall drying of the climate transpires in the coming decades as widely predicted, water levels will continue to fall. Further, it is probable that the Trinity aquifer in the Hill Country is partly recharged by discharge from the Plateau system so that abstraction on the Plateau may impact expanding Hill Country population centers.

Prior to this study no one has attempted, in a regionally comprehensive fashion, to document the interactions between Plateau and Plateau-adjacent aquifer systems or the controls by those systems on the quality of any of the major rivers that bound the Plateau. Apart from characterizing an environmentally and economically significant hydrogeologic system, however, the variety of hydrochemical and isotopic data that have been collected during this study have provided opportunities to develop and critically examine hypotheses concerning paleo-flow systems, to develop tools that enable recharge evaluations with much greater spatial resolution than are usually practical, and to demonstrate that it is possible to interpret river hydrochemical evolution in terms of the hydrochemistry of aquifers with which it is in hydraulic communication.

Although not a prime objective of this research, I aspired that it would lead to development of practical tools for responsible exploitation of groundwater resources. In a world of increasing pressure from expanding populations and heightened material expectations that draw increasingly on limited natural resources, high-level research that improves the probability that the managerial class will make responsible decisions concerning resource use is highly desirable. In this project I discovered that certain basic data that is routinely generated in water analyses can be used as proxies for more sophisticated data sets that are expensive to develop. Although more sophisticated hydrochemical and isotopic data may more directly define critical recharge and flow parameters, their availability on closely-spaced spatial or temporal intervals over regionally extensive aquifer systems such as the Plateau system is far into the future, if it is ever available sufficiently. Further, hydrochemistry may provide a lens through which

to interpret regional, even local, flow patterns where hydrodynamic techniques are likely to be complicated by geologic structure (including fractures and karst) that is practically impossible to resolve spatially through pumping tests. To be successful, such hydrodynamic testing requires well spacing that is prohibitively expensive. I consider the findings, especially those discussed in Chapter 2 of this dissertation, to have the potential impact that I describe.

Observations and Hypotheses

The initial impression one gets when viewing a map of any hydrochemical parameter prepared for either the Edwards or Antlers aquifer units of the Plateau system is one of notable spatial variability. Likewise, comparison between Edwards and Antlers hydrochemistry reveals significant differences in constituent concentrations and constituent ratios between the two units. For example, salinity and $\%SO_4$ is much higher overall in the Antlers than in the Edwards; and isotopic data (^{14}C, ^{3}H, δD, and $\delta^{18}O$) suggest that Antlers water is overall older and was recharged at lower temperatures than that from the Edwards. The aquifers generally are sufficiently dissimilar hydrochemically that it appears that they may be hydraulically isolated from one another. Further investigation suggests that this impression is erroneous, however. Although groundwater in the Antlers is generally of lower quality (i.e., higher salinity) than that in the Edwards, constituent ratios in some areas of the Edwards are similar to those in much of the Antlers. Further, the distribution of Antlers-like constituent ratios in the Edwards appears topographically, hence geographically, systematic. Finally, isotopic values in some

Edwards samples are intermediate between the low values of percent modern carbon, tritium concentration, and $\delta^{18}O$ that characterizes most of the Antlers and the significantly higher values that characterize most of the Edwards samples. Thus, mixing within the Edwards of Antlers-derived groundwater and modern meteoric recharge that has resided entirely in the Edwards is suggested.

These observations led me to formulate the following hypotheses:
1) Edwards groundwater with conspicuously elevated $\%SO_4$ values contains a significant and measurable fraction of water derived from the Antlers; 2) Antlers groundwater was injected into the Edwards aquifer under a hydraulic paleo-gradient that promoted upward flow; 3) under the modern hydraulic gradient that promotes downward and lateral flow in the Plateau system higher-SO_4 groundwater is being diluted or displaced by low-SO4 recharge originating on the Edwards Plateau; 4) recharge is preferentially occurring in losing-stream networks and inhibited along the drainage divides, and 5) relative recharge rates can be calculated on a local basis from knowledge of certain constituent ratios. The first two papers address these hypotheses.

The third paper addresses hypotheses that I developed during a project that sought to discover the source of contamination to the Upper Colorado River, a conspicuously saline stream whose valley bounds the northern margin of the Edwards Plateau. The river is most saline in its most upstream reaches and freshens overall downstream with a couple of local reversals in the freshening trend. Although the river traverses several Triassic and Permian aquifer systems in the study area that extend under the Plateau system, as well as traversing prolific hydrocarbon producing areas, it does not contact the

Plateau system. Nonetheless, certain hydrochemical characteristics in the river and hydrochemical distributions in the groundwater of aquifers that the stream contacts suggests that groundwater discharged from the Plateau is influencing the chemistry of groundwater and surface water away from the Plateau. These observations led me to formulate the following hypotheses: 1) elevated salinity in the Upper Colorado River is caused by significant content of water derived from deep aquifers containing brines similar to produced water associated with hydrocarbon production and brine originating in halite-dissolution zones; 2) downstream decrease in surface water salinity is caused by increasing content of Plateau-derived groundwater that traverses Triassic and Permian shallow-aquifers; 3) downstream salinity decreases also reflect increased base flow rates arising from increased aquifer recharge rates that, in turn, reflect patterns of increased mean annual rainfall; and 4) reversals in overall downstream surface- and shallow groundwater hydrochemical trends are caused by local injections of brines from deep aquifers in the vicinity of oilfields.

Organization and Approaches

This dissertation contains three papers that address three basic issues concerning Plateau groundwater: 1) the origins of Plateau groundwater, 2) how is recharge being distributed across the Plateau, and 3) impacts of the Plateau system and contiguous aquifers on the quality of a major stream in the region.

The first paper uses conservative mixing models in conjunction with analyses of basic hydrochemical constituents, stable isotopes of strontium, oxygen, and hydrogen,

and cosmogenic isotopes of hydrogen (^{2}H, or deuterium) and carbon (^{14}C, or radiocarbon) to support the hypothesis that groundwater in the Edwards carbonate aquifer records a geographically variable mixture of relatively modern meteoric recharge and sulfate-enriched groundwater from subjacent aquifers that were recharged under cooler climatic conditions during the Pleistocene. Further, the geographic hydrochemical variability is shown to reflect topographically and stratigraphically controlled recharge processes. One of the practical values of this paper is that it attributes to natural processes much of the contamination of Plateau groundwater often blamed on hydrocarbon industry practices.

The second paper uses the systematic correspondence of radiocarbon apparent groundwater age, tritium content, and their correlations to groundwater Mg/Ca values to map recharge windows into the Edwards aquifer and, by establishing a reasonably predictable relationship between Mg/Ca and fraction of modern recharge, suggest a method to calculate mean annual recharge volumes on a per-well basis. This paper also explores quantitatively the profound influence on apparent age of mixing modern and ancient groundwater, effects that may overshadow the often considered "apparent groundwater aging" phenomena caused by addition to groundwater of non-radiogenic carbon during carbonate dissolution or loss of radiocarbon through processes such as ion-exchange. One of the practical values of this paper is that it provides a reasonable method to evaluate recharge on a local basis from regional estimates of recharge rates produced from regional groundwater models, thus enabling water district managers to assign scientifically-supported location-based limits on pumpage.

The third paper documents the downstream hydrochemical evolution of Upper Colorado River water where the stream most closely approaches the Edwards Plateau and qualitatively interprets the relative effects of inputs via base flow of halite-dissolution brines, brines from deep Permian and Pennsylvanian aquifers, and groundwaters from several Mesozoic and Permian aquifer systems where discharge from the Plateau system is proposed to exert the dominant control.

Although samples from 69 locations were collected and analyzed for this project, the overall study of the Plateau and associated aquifer systems has a regional scope with a study area approaching 25,000 sq. mi. and uses thousands of data generated from water analyses performed over a span of several decades. Therefore, the results that show systematic patterns necessarily are interpreted to reflect regional-scale processes that are prevalent in spite of temporal variations that may have occurred locally during any particular sampling period. The writer feels that the present work provides a strong basis from which future investigations with more restricted geographic and temporal focus might proceed.

The three papers are designed to stand alone and, therefore, contain some redundant introductory information because the study areas in the three papers are coincident or overlap to some extent. However, effort was made to tailor these sections to serve the hydrogeologic issues being addressed in each paper.

A philosophical comment seems appropriate. I undertook this project mostly as a vehicle for personal growth. I began it while involved in sporadic geologic consulting

that, while occasionally lucrative, did not provide the level of intellectual stimulation that I had discovered was essential. Also missing was a sense that I was producing anything of lasting value or that I was advancing sufficiently the geoscience discipline to which I had dedicated my professional life. I believe that this project has produced results that advance hydrogeologic science in a practical way and that my approaches have broader hydrogeological applications beyond my study area.

CHAPTER 1

MIXING BETWEEN ANCIENT AND MODERN GROUNDWATER IN THE EDWARDS PLATEAU, TEXAS: EVIDENCE FROM DISSOLVED SULFATE, STABLE ISOTOPES, AND RADIOGENIC ISOTOPES

ABSTRACT

Groundwater in the Edwards-Trinity (Plateau) aquifer system of Texas exhibits stratigraphic and geographical variability in major ion concentrations and isotopes of Sr, O, H, and C. Based on SO_4/TDS values that suggest the presence of several hydrochemically distinct water types, and between $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ values, Plateau groundwater composition reflects complex and geographically variable multi-component mixing between 1) modern rainwater, 2) recent recharge to the Antlers aquifer through the superjacent High Plains (Ogallala) aquifer, 3) Pleistocene-age, high-SO_4 /TDS water (SO_4/TDS>0.15) originating in Antlers aquifer and subjacent Permian aquifers; and 4) young low-SO_4/TDS water (SO_4/TDS<0.15) from the karstic uppermost carbonate aquifer (Edwards) of the system.

Proposed transmission of dissolved Permian sulfate into the Antlers and Edwards aquifers requires hydraulic head distributions that promote upward flow, although lateral flow from Permian strata into Antlers incised-channel sandstone may occur locally. Upward flow into the Edwards is best explained by recharge at elevations greater than those that are characteristic of the Plateau. $\delta^{18}O$ values range from a minimum of –8.82‰ in the Antlers aquifer to a maximum of -4.23‰ in the Edwards aquifer. $\delta^{18}O$-based maximum temperature differences between samples of SO_4-enriched, ^{14}C-, ^{18}O- and D-

depleted Antlers groundwater, and SO_4-depleted, ^{14}C-enriched Edwards groundwater are approximately 6°C. Such low recharge temperatures are consistent with recharge of the Antlers occurring under cooler conditions than prevail on the Plateau today, perhaps at elevations over 6,000 ft above mean sea level in the Southern Rocky Mountains of New Mexico. West-east flow paths from the Rockies into the Edwards Plateau were probably diverted into the south-trending Pecos River valley that was developed during the Pleistocene in response to subsidence produced by dissolution of widespread Upper Permian halite. This development would have interrupted hydraulic continuity between the highland recharge areas and the Plateau system and produced hydraulic head distributions that promote downward flow in the Plateau system.

The highest concentrations of Antlers-dominated groundwater produced by wells completed in the Edwards aquifer within a three-county focus area occur in north-central Crockett County where groundwater with the highest SO_4/TDS values (>0.3) occur. Upward flow into the Edwards may have been retarded in the southern part of the area where Glen Rose Formation carbonate rocks occur stratigraphically between the Antlers and Edwards aquifers. Relative abundance of dissolved sulfate in Edwards water generally diminishes with distance from the area characterized by the highest SO_4/TDS values. Reduced SO_4/TDS values toward the eastern part of the study area correlate generally with inferred increasing recharge rates in areas with greater mean annual rainfall, and larger fractions of groundwater that are equilibrated with the sulfate-poor Edwards aquifer carbonate rocks. Dilution is retarded in these areas by geomorphic features that inhibit recharge, such as low-permeability soils developed on Middle

Cretaceous (Washita Series) strata along drainage divides. Maintenance of high salinities in the Antlers aquifer reflects its confinement by low-permeability strata at the base of the Edwards.

INTRODUCTION

The Edwards-Trinity (Plateau) aquifer system consists of carbonate strata that dominate its upper part, and siliciclastic strata that dominate its lower part. Flow systems in carbonate aquifers are difficult precisely to map because the flow networks are invisible and largely are the result of post-depositional diagenetic processes, the controls on which are not simple and not understood in detail. Further, avenues for direct precipitation recharge may be controlled by soil characteristics that reflect the composition of parent rock and by other geomorphic characteristics such as distribution and depth of penetration by karst features that extend from the land surface. Identification and evaluation of regional karst flow systems at a level of detail required for proper groundwater resource management are beyond the practical capabilities of geologic mapping and hydrodynamic testing. In systems where cross-formational flow occurs between mineralogical and architecturally dissimilar units the difficulties are even greater. These issues are pertinent to investigation of the Plateau system.

A helpful approach involves analyses of hydrochemical and isotope data. Conservative hydrochemical and isotope constituents may act as natural tracers. Tracers may be locally tied to specific origins in the geologic section, and may reflect relatively simple processes such as mixing between groundwaters with different origins. As is demonstrated here, in some cases basic hydrochemical data can be used as dependable

proxies for less abundant isotope data. The predictable correspondences between basic data and isotope data that can be interpreted to indicate relative groundwater age or recharge temperatures enables interpretations of regional flow systems, possibly at a cost that is within the available modest budgets of agencies charged with managing water resources.

This paper, as well as another in this dissertation, uses interpretations of hydrochemical and isotope constituents distributions in the Plateau system, and systematic relationships between the data types, to elucidate the hydrodynamics of this system to an extent not been previously achieved.

Hydrogeological Setting of the Plateau Aquifer System

The Plateau aquifer system consists of relatively flat-lying, generally southeast-dipping Lower Cretaceous siliciclastic and carbonate strata in the Edwards Plateau of west-central and western Texas (Fig. 1.1). The 23,400 sq. mi. (60,606 sq. km.) Plateau ranges from approximately 1,000 ft to 3,400 ft (305 m to 1,035 m) in elevation above mean sea level and encompasses all or part of 21 counties. It is bounded along its southwestern margin by the Rio Grande River valley, along its northwestern margin by the Pecos River valley, along its eastern margin by the Colorado River valley, and along its southern margin by several valley systems whose rivers originate within reentrants along the Plateau margin. Along its northwest margin the Plateau merges with the Southern High Plains. Topography is flat to rolling along divides, but locally exhibits steep cliffs, mesas, and buttes near streams. Streams upon the Plateau are intermittent and

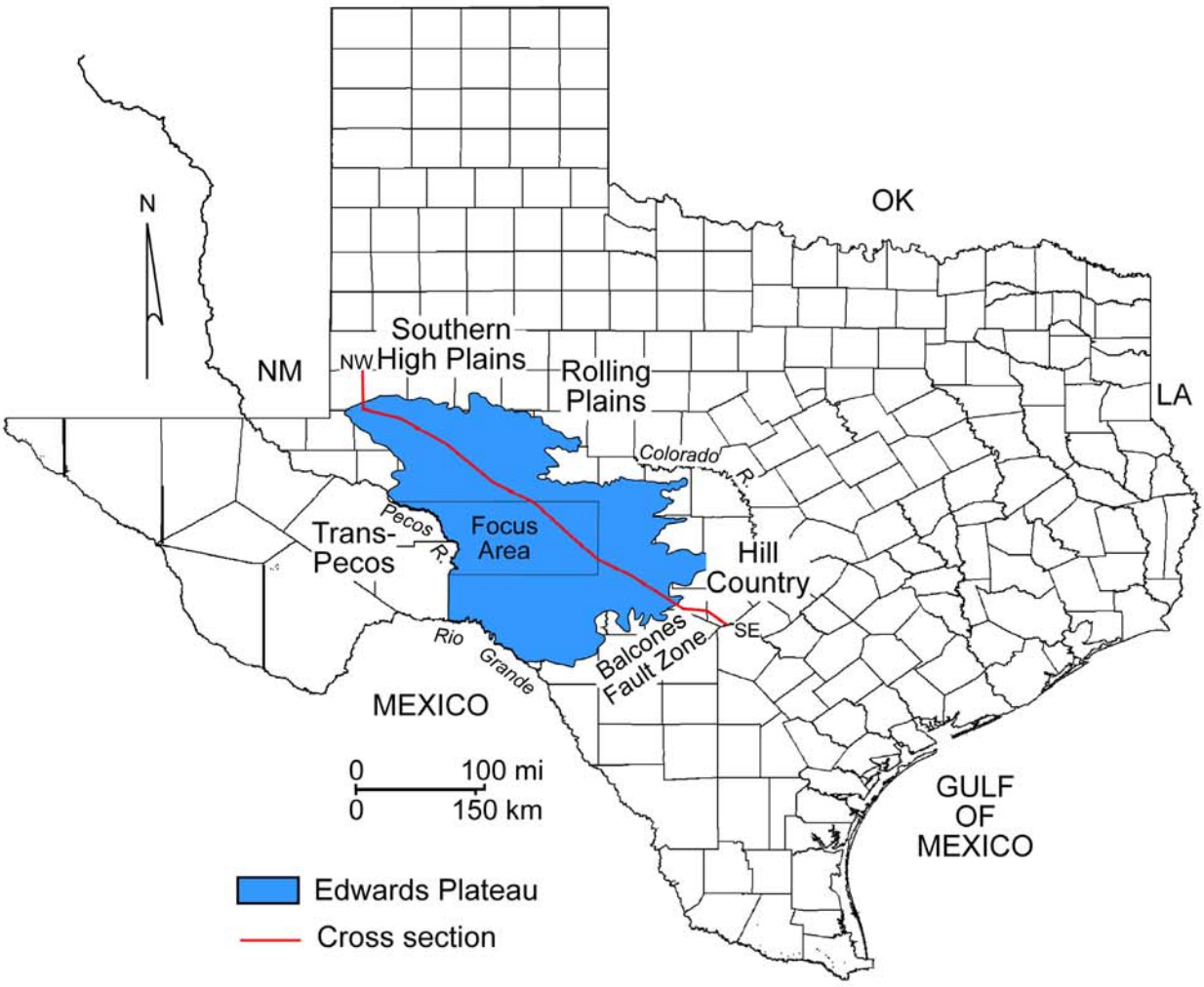

Figure 1.1. Location of Edwards Plateau and three-county focus area. Also shown is the extent of the Pecos River into central New Mexico and location of cross section shown in Figure 1.4.

stream beds compose the primary precipitation recharge windows to the Plateau system. Springs are not common on the Plateau but some occur at bedding plains along Plateau margins, most markedly from the boundary between the Edwards and Trinity aquifers.

Plateau climate, from east to west, ranges from semi-arid to sub-humid. Mean annual rainfall ranges from 14 in to 30 in (355.6 mm to 762 mm) (Fig. 1.2) (Larkin and Bomar, 1983). Timing and distribution of rainfall usually depends on collisions of east- to southeast-moving air masses containing Pacific-derived moisture with northwest-moving air masses containing moisture from the Gulf of Mexico. On average, rainfall intensity peaks in September, based on records from Sonora (Sutton County). However, monthly rainfall measuring close to 6 in (152.4 mm) or more has been recorded historically for most months between April and October. Regionally, average low temperatures range from 10^{o}C to 13^{o}C and average high temperatures range from 25^{o}C to 28^{o}C, averaging 17^{o}C to 21^{o}C annually.

The extent of the Plateau system is defined by the limits of a continuous surface on Fredericksburg/Washita Group rocks (Fig. 1.3). The Plateau system comprises Lower Cretaceous strata of the Trinity, Fredericksburg, and Washita Groups (Fig. 1.4). The primary Trinity strata in the study area include the sandstone-dominated Antlers and Hensell Formations, and the carbonate-dominated Glen Rose Formation. Although each of these units is considered an aquifer in groundwater data bases (TWDB, 2008), they are often referred to collectively as the Trinity aquifer. Fredericksburg/Washita strata include the Ft. Terrett, Segovia, Ft. Lancaster, Buda, Devils River, West Nueces, McKnight, and Salmon Peak Formations. These are often referred to collectively as the Edwards aquifer

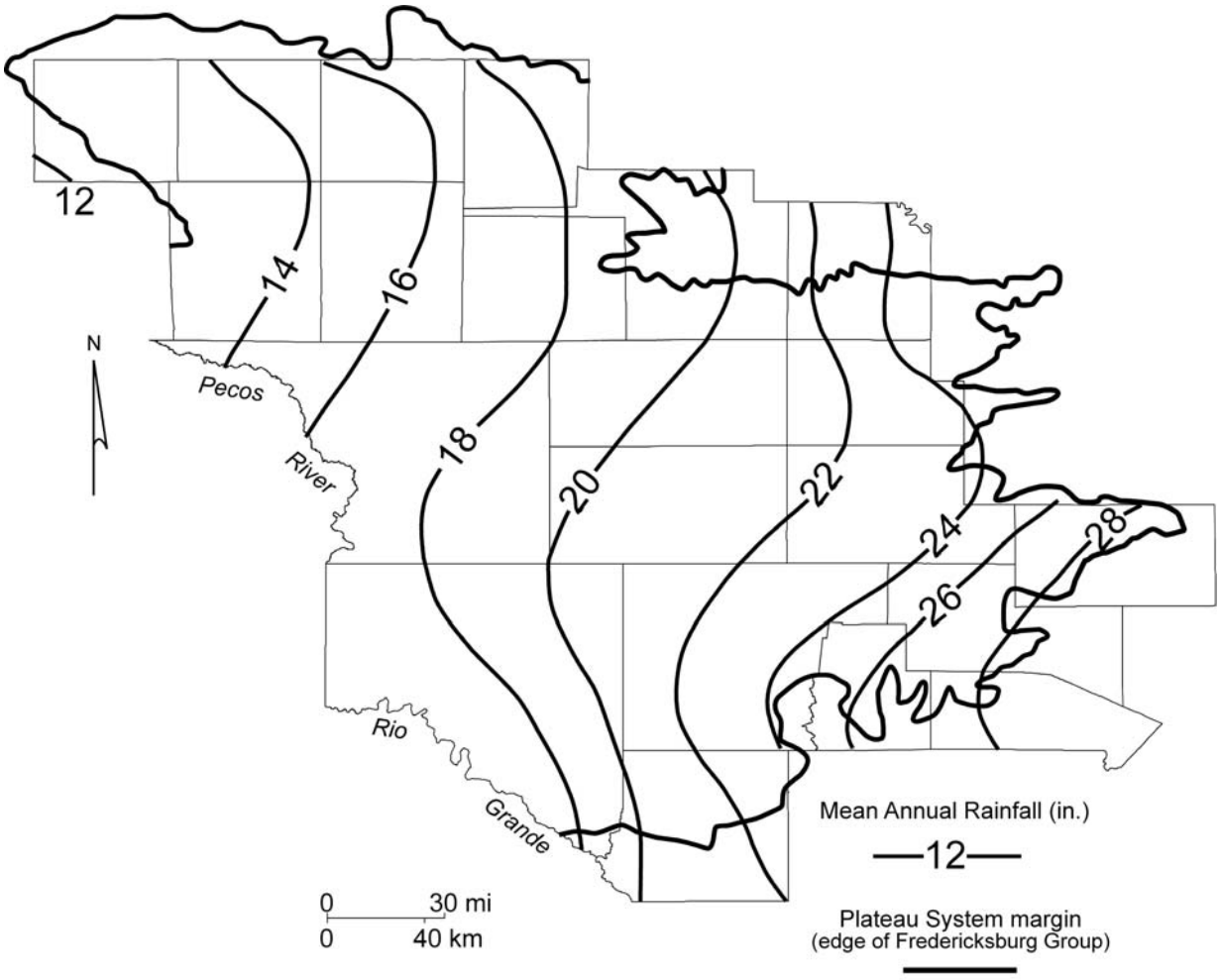

Figure 1.2. Distribution of mean annual rainfall for the study area based on 1951-1980 data. Peak rainfall occurs in late spring and late summer, on average. Data from Larkin and Bomar (1983).

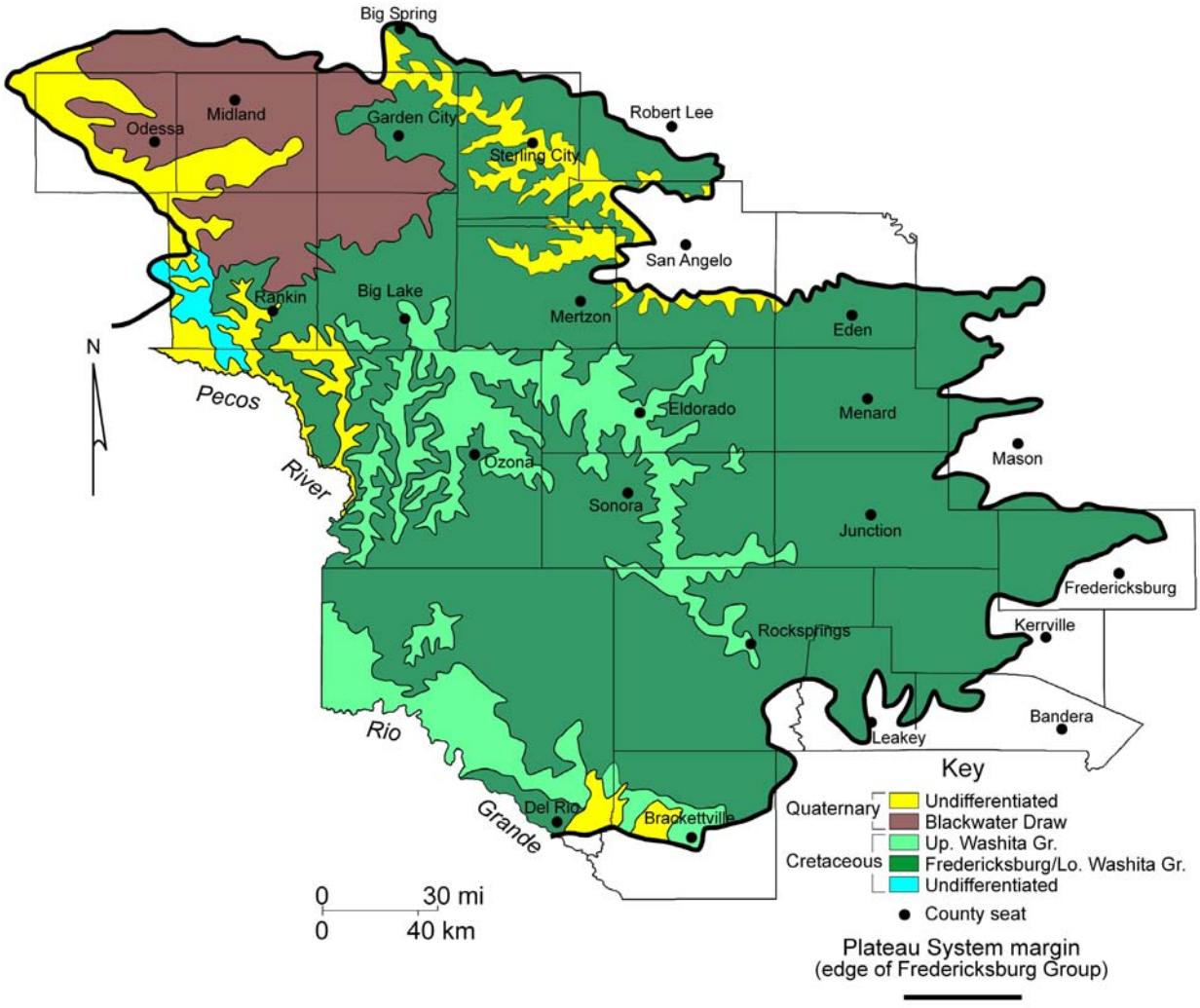

Figure 1.3. Simplified geological map of the Edwards Plateau. Plateau aquifer system is defined by continuous extent of Fredericksburg/Washita Group strata. Also shown are county boundaries and county seats.

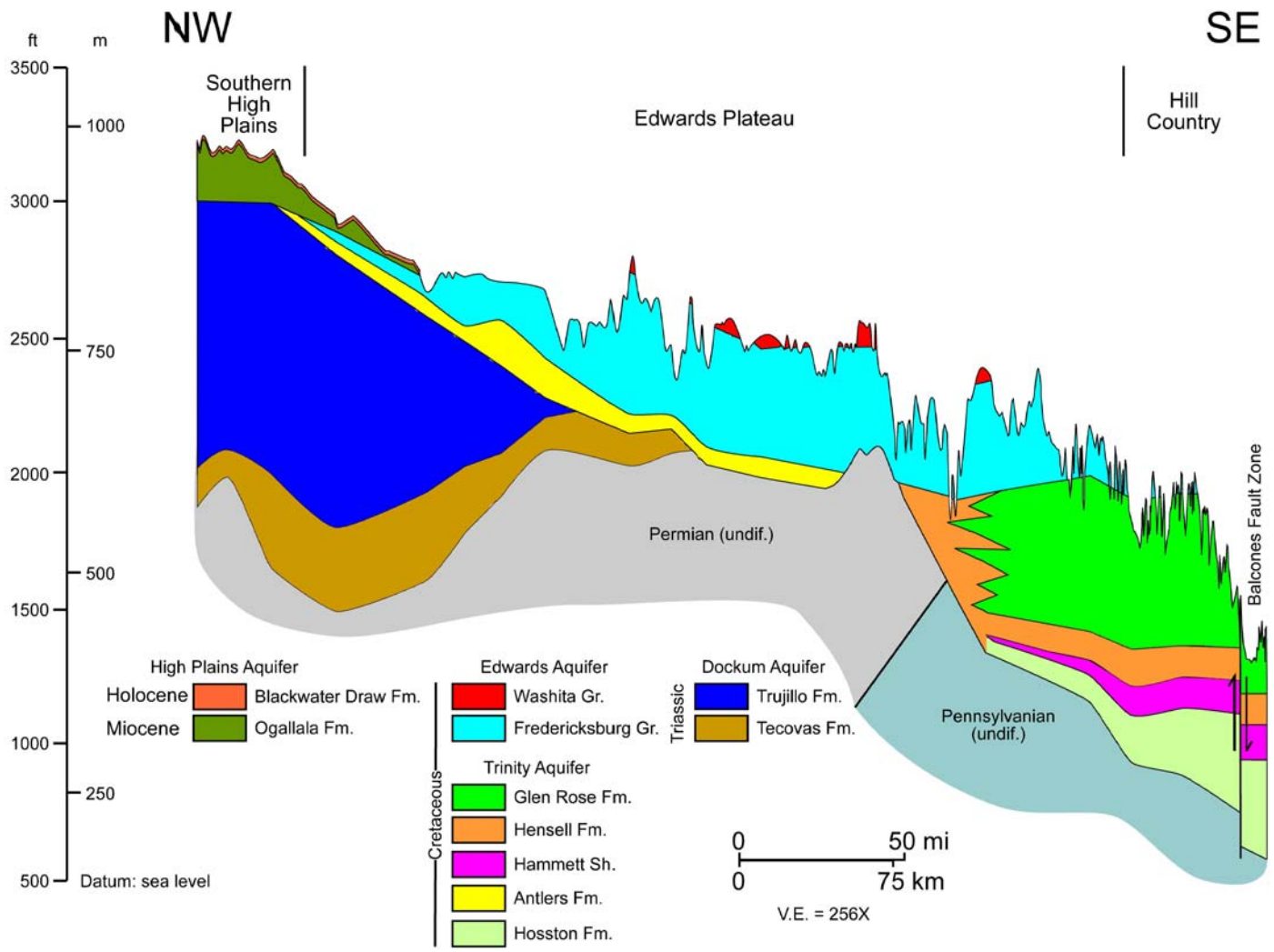

Figure 1.4. Northwest to southeast schematic hydrogeological cross section of the Edwards Plateau showing Cretaceous and contiguous aquifers. Vertical exaggeration is 256X. Modified from Barker and Ardis (1996).

in recognition of their age-equivalence to Edwards Group strata in the Balcones Fault Zone and under the Gulf Coastal Plain (Rose, 1972). Among these the Antlers, Glen Rose, and Edwards aquifers are of primary interest in this study.

The configuration of the potentiometric surface of the Plateau system (Fig. 1.5) subtly mimics regional topography, with local perturbations (drawdown) near widely spaced municipalities. Water well depths range from less than 50 ft in drainages near the Plateau margin to over 400 ft upon the most elevated divides. Based on storativity values (0.00006 to 0.0003) calculated from pump tests (TWDB, 1969) the Antlers aquifer is confined to semi-confined, at least locally. Reports from some parts of the area indicate that the potentiometric surface of Antlers water is above the top of the formation, but declines to levels below the formation top near major drainages such as the Pecos River valley (Fig. 1.1) (e.g., White, 1968). These observations suggest that the Antlers is probably generally confined in the more interior parts of the Plateau, but unconfined toward the perimeter of the Plateau. Perhaps more significantly related to hydrochemical issues explored below is that the Santa Rosa aquifer, in the Dockum Group of Triassic-age, is confined by the overlying low-permeability part of the Dockum Group. In wells penetrating the Santa Rosa water levels have been observed to rise almost to the top of the Triassic section. The Edwards is probably widely unconfined, based on the widespread occurrence of karst and caves. However, pump tests in the Edwards are uncommon. The presence of a low-permeability interval at the base of the Edwards has been documented (White, 1968; Walker, 1979), which explains the confinement of the

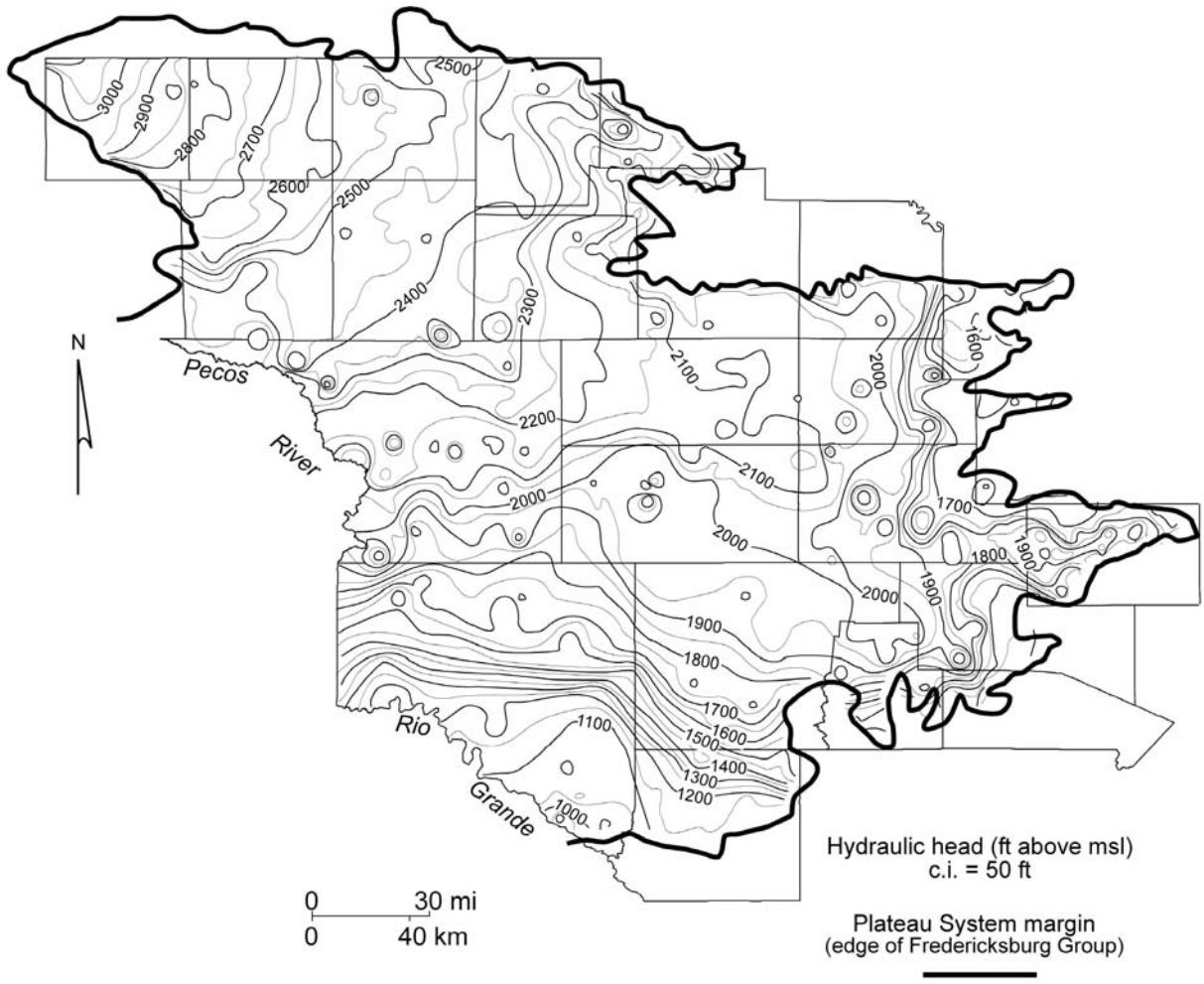

Figure 1.5. Elevation of the potentiometric surface of groundwater in the Plateau aquifer system. Surface approximately mimics regional topography with higher gradients occurring in the vicinity of larger stream drainages. Data are measurements made during and since 1979 (TWDB, 2007).

underlying Antlers and the occurrence of springs along the Plateau margins at the base of the Edwards.

Effective porosity in the Antlers sandstone aquifer is considered to be interparticle, whereas karst is important in the Edwards carbonate (Walker, 1979). The most water-productive part of the Edwards has been suggested to be a dissolution-modified stratiform interval near the base of the aquifer (Rose, 1972). The role of fractures has not been comprehensively evaluated for Plateau hydrogeology, although the probable influence of fractures on Plateau cave development has been discussed (e.g., Kastning, 1983; Wermund and others, 1978), and the apparent general control of fractures on Plateau cave morphology is strongly suggested by maps of Plateau caves (e.g., Kastning, 1983; Elliot and Veni, 1994).

The Plateau system is underlain by Triassic and Upper Paleozoic units (Barker and Ardis, 1992) and overlain by Cenozoic to recent units (e.g., Nativ, 1988) whose ancestral and present hydraulic relationships with the Plateau system are important to understand if Plateau system hydrochemistry is to be understood. The hydrogeological framework of the Plateau aquifer system isdescribed by Barker and Ardis (1996).

Previous Investigations

Previous workers have developed regional-scale information on the Plateau system focusing on the hydrogeological setting (Walker, 1979; Barker and others, 1992, 1996), distribution of hydraulic heads (Kunianski, 1990; Bush and others, 1993), and flow models (Kunianski, 1994).

Reports of more local features that provide important insights into Plateau system hydrodynamics include work on cave systems in the Plateau (e.g., Kastning, 1983; Veni, 1994) and Plateau fracture systems (Wermund and others, 1978).

Prior to the present study the only hydrochemical investigations of regional scope for the Edwards-Trinity (Plateau) aquifer system are those of Walker (1979) that provided the first summary of water quality in the Edwards Plateau which focused on distributions of salinity values and major anionic species based on analyses of widely spaced wells; Bush and others (1994) that summarized the distribution of dissolved solids and hydrochemical facies based on averaging analyses of multiple wells in areas of predetermined dimensions (6 mi × 6 mi); and Nance (2004) that focused on patterns of anionic hydrochemical variability based on analyses of individual wells, and presented evidence that ion exchange was a probably a major influence on stratigraphically variable cation distributions in the Plateau system.

Much of the data and hydrological interpretations presented in this paper are new for the Edwards Plateau, provide a sound basis for future study, and should find applications in analyses of other aquifers whose ancestral flow systems may have shifted markedly to their present configurations.

METHODS

Samples were collected from wells with activated submersible pumps after pH, temperature, and electrical conductivity values stabilized. Field parameters were monitored for stabilization with a Hach Hydrolab Quanta multi-probe. Samples for

cations and anions were passed through 0.45μ non-reactive syringe filters into separate containers. Splits for cation analysis were stabilized with nitric acid; splits for NO_3^- were stabilized with sulfuric acid. Splits for anions and isotopes of oxygen, hydrogen, strontium, and carbon were untreated. All samples were placed on ice and maintained at approximately 4°C until received by the analytical laboratories.

Major and minor ions were analyzed by standard methods at Energy Laboratories (Casper, WY).

Strontium isotope analyses were performed at the University of Texas, Jackson School of Geosciences on a Finnigan-MAT 261 thermal ionization mass spectrometer using auto-dynamic techniques. A volume of water containing at least 250 mg of Sr was pipetted into a Savillex Teflon vial containing 50 microliters of 7 N HNO_3 (to convert any HCO_3^- to NO_3^-). The sample was dried and the Sr was isolated using Eichrom Sr-specific resin. Samples were loaded onto zone-refined Re filaments along with 0.3 M H_3PO_4 and Ta_2O_5. Procedural blanks were consistently less than 15 pg of Sr. Results were normalized for fractionation to $^{86}Sr/^{88}Sr = 0.1194$ using an exponential fractionation law. A mean value of 0.710261 was determined for standard analyses of NIST-SRM 987 (external 2ρ = +/-0.000015 for auto-dynamic runs, n = 50).

Stable-hydrogen- and oxygen-isotope analyses were performed at Southern Methodist University. For $\delta^{18}O$ analysis two to five mL of sample water is equilibrated overnight at 25°C with CO_2 gas of known carbon isotopic composition. The equilibrated CO_2 gas is cryogenically purified, loaded into a sample tube, and is analyzed on a mass spectrometer. At least one in-house laboratory standard is analyzed with each set of

unknown samples (no less than one for every 15 samples). Results from the standard runs indicate an analytical precision of $\leq \pm 0.10$ ‰. As a secondary check, the carbon isotopic composition of the CO_2 gas obtained from the procedure is compared to the initial carbon isotopic composition of the CO_2 equilibration gas.

For δD analyses five μL of cryogenically purified sample water is reduced to H_2 gas by passing it over depleted uranium metal at 800°C. The H_2 gas is collected onto activated carbon at liquid nitrogen temperature. Results from the standard runs and from duplicate analyses indicate an analytical precision of approximately ± 1 ‰. All isotopic measurements are made on either a Finnigan MAT 251 or Finnigan MAT 252 mass spectrometer. In-house standards, which are calibrated with international standards, are run with each batch of samples as a check on procedural uniformity. Every fifth sample is repeated as a check on reproducibility.

Tritium activity analyses were performed by using the gas proportional counting method at the Tritium Laboratory at the University of Miami, Rosenstiel School of Marine and Atmospheric Science. 300 mL of the water sample are distilled with continuous reflux to dryness or near dryness. During the procedure, the still is vented to the ambient air through a drying agent to avoid contamination of the sample by atmospheric water vapor. The volume of the sample is reduced from 275 to 5 mL while preserving a large fraction of the tritium. The normal starting volume is 275 mL of which 75 mL are charged into an electrolytic enrichment cell. To that portion, 2 mL of concentrated sodium hydroxide solution (made from dead water and sodium peroxide or oxide) is added, and the remainder of the sample is transferred to a container on top of the

cell. The sample is electrolyzed for 24 hours at 5 amps, current-regulated, which removes 50 mL of water. Once a day the solution in the cell is topped up from the container to the 75 mL mark, and the procedure is continued. When a total of between 20 and 50 mL of the sample remains, power is changed to constant voltage of 3.15 V, and later reduced to 2.75 V, until the process stops at the lower edge of the anode, leaving about 5g of enriched sample. This procedure takes 10 - 14 days, and the remaining amount of water typically contains 80% of the original amount of tritium. The enriched water sample is vacuum distilled from the sodium hydroxide, and the yield is weighed to – 2 mg, and the value is adjusted for hydrogen left in the sodium hydroxide. About 3 mL of the enriched water sample is injected into a vacuum system. The water evaporates, and the vapor is reduced by hot magnesium metal to hydrogen gas which is absorbed on activated charcoal at liquid nitrogen temperature in a stainless steel pressure cylinder. Approximately 4 L atm of hydrogen is obtained this way. The low-level gas proportional counters have an active volume of 1 L and are shielded by 2.5 cm of selected lead, a ring of anti-coincidence Geiger counters, 10 cm of paraffin wax, boric acid and/or borated polyethylene, and at least 20 cm of iron, plus the walls and ceiling of the building. The counter is first filled with 10 psi (67 kPa) of propane. Thereafter, the sample hydrogen gas, under pressure in its cylinder, is added to the counter for a total pressure of 40 psi (300 kPa). The counter is then sealed off, and the gas amplification is set to specifications by adjusting working voltage using an external radioactive source. After that, counting proceeds until criteria for accuracy or sensitivity have been met. The pulses are sorted into several channels, of which some are used for continuous control of the gas

amplification, as shown in the cosmic radiation spectrum, etc. Counting times are 6 to 20 hours. A 1 TU original sample enriched from 275 to 6 mL typically shows 0.6 cpm in the tritium channel above a background of 0.40 cpm, known to – 0.02 cpm. At least once weekly each counter counts dead hydrogen gas (from petroleum). In addition, water from the deep Floridan Aquifer (more than 10,000 years old water) is reduced to occasionally check on the tank hydrogen gas. This procedure sets the background count of the counting equipment. Each batch of sodium hydroxide solution is also tested for blank value. A further check on process blanks is that at least once a week a sample of dead water (from the Floridan Aquifer) goes through all the same procedures, including enrichment, as the unknown samples. In order to check on the efficiency of the enrichment procedure, at least once a week a sample of known activity is processed through the entire system of enrichment, reduction, and counting. The efficiency of each counter is determined by counting hydrogen gas made by reduction of standard water in our regular preparation system. This standard water is prepared from NIST (formerly United States National Bureau of Standards) SRM #4926 by dilution by weighing. The dependence of background, efficiency, etc., on pressure, gas composition, gas amplification, etc., is known, and the appropriate corrections are applied via the software of the computing system.

Radiocarbon (^{14}C) analyses were performed at Beta Analytic Inc. in Miami, Florida by using the AMS method. Groundwater apparent ages were calculated from percent modern carbon (pmC) by Beta Analytic assuming initial ^{14}C activity to be 100% of modern activity with a half-life of 5,568 years. Results are derived from reduction of

sample carbon to graphite (100 %C), along with standards and backgrounds. The graphite is then sent for ^{14}C measurement in an accelerator-mass-spectrometer located at one of six collaborating research facilities, who return the results to Beta for verification, isotopic fractionation correction, calendar calibration, and reporting. The standard for modern carbon is Oxalic Acid II obtained from National Institute of Standards and Technology. $\delta^{13}C$ values also were determined during this procedure.

Databases were manipulated and statistics reduced in Microsoft Excel. Mapping was initially performed in ESRI ArcGIS and finalized in Macromedia Freehand.

Hydrochemical and isotopic data used for this project were acquired from analyses of samples obtained from water wells completed in the carbonate (limestone and dolostone) Edwards aquifer on the Edwards Plateau. Wells completed in this interval are typically open-hole completions (Walker, 1979). Data on exact completion depths are not available for every well and the condition of individual boreholes is very poorly known, including the distribution of natural fractures. Driller's reports suggest that solution cavities are common and widespread, although their connectivity is unknown. For these reasons stratigraphic control for sample origin is limited to aquifer interval, the identity of which has been determined by the Texas Water Development Board.

DATA

Data for this study include charge-balanced (+/- 5%) hydrochemical analyses performed during or after 1960 for over 3,980 wells completed in the Plateau aquifer system and Ogallala aquifer on the Edwards Plateau and Southern High Plains (Fig. 1.6).

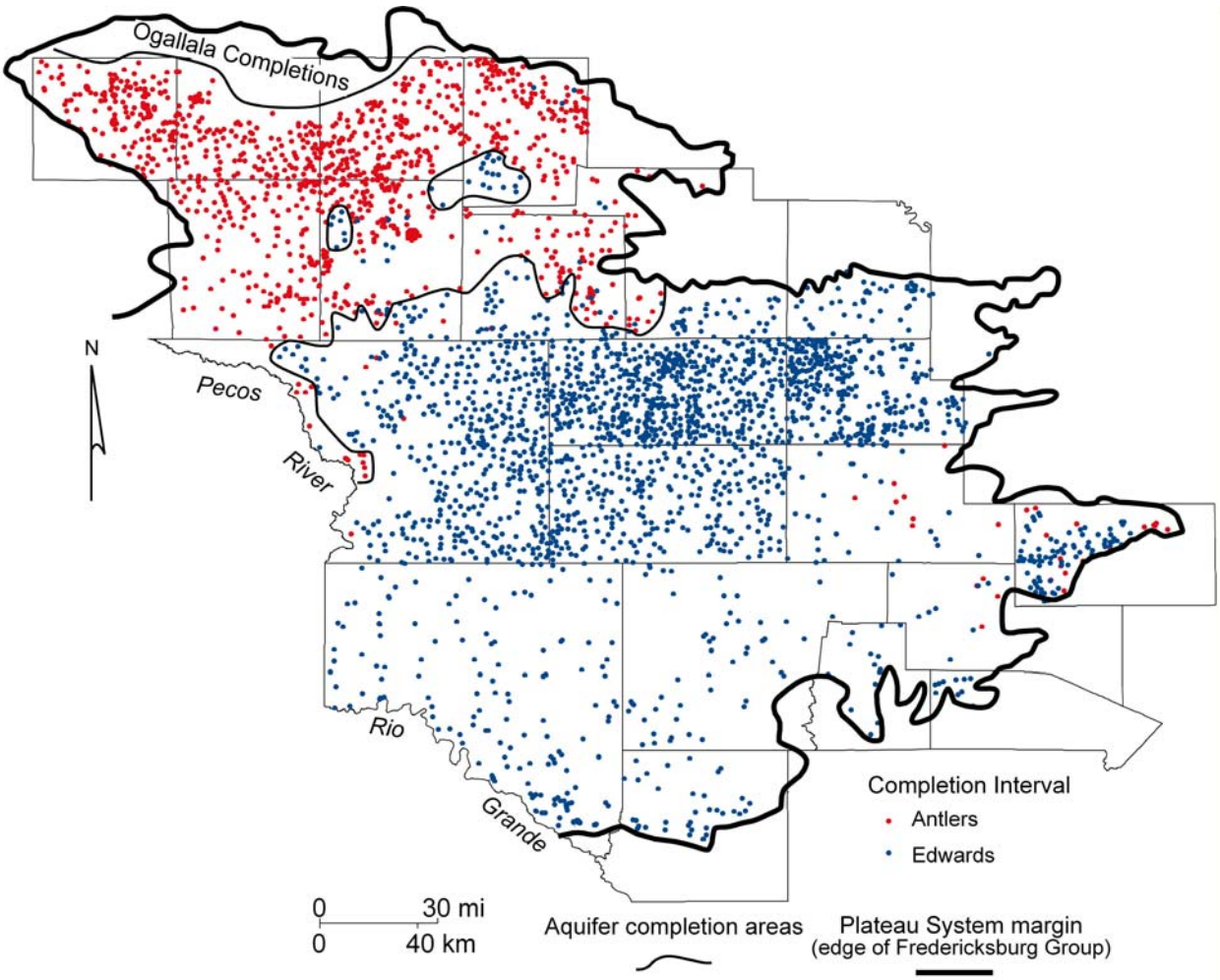

Figure 1.6. Location map of selected wells registered with the Texas Water Development Board. Individual wells are reported to be completed in one of two Cretaceous stratigraphic intervals. Wells completed in multiple intervals are not included. Boundary lines drawn between areas that are characterized by well completions in specific aquifers are shown and are used in other figures where well locations are not shown. County boundaries also are shown. Well data from TWDB (2007).

The online well database is maintained by the Texas Water Development Board (TWDB, 2008). Each of the wells was reported to be completed entirely in one of the three aquifers that are the focus of this study (TWDB, 2008). Additional data was developed by the writer during a sampling campaign undertaken in 2006 and 2007 for which groundwater samples from 69 wells were collected for analyses of major and common minor ions, and for isotopes of strontium (^{87}Sr, ^{86}Sr,), oxygen ($\delta^{18}O$), hydrogen (^{1}H, ^{2}H, ^{3}H), and carbon ($\delta\ ^{13}C$, pmC).

RESULTS

This paper uses brackets to indicate ionic concentration (e.g., $[Ca^{2+}]$), whereas brackets and ionic charges are eliminated for ratios (e.g., Mg/Ca).

Aquifer-specific Constituents of Plateau System Groundwaters

The ranges of concentrations, average concentrations, and median concentrations for hydrochemical and isotopic constituents of Antlers groundwater are significantly different from those of Edwards groundwater. Examples of where the compositional ranges of water from these separate aquifers overlap are important in considering the sources for chemical and isotopic constituents, potential mixing relations between groundwaters with different origins and flow histories, and controls on constituent dispersal.

Total Dissolved Solids

Antlers groundwater, on average, contains a significantly greater [TDS] than Edwards groundwater does. In the Antlers [TDS] ranges approximately from 200 to greater than 27,000 mg/L and averages approximately 1,000 mg/L, whereas [TDS] in the Edwards ranges approximately from 100 to 8,200 mg/L and averages approximately 400 mg/L (TWDB, 2008). Samples collected for this study also show greater salinities for Antlers water (A1.1). It is notable that the very highest [TDS] values for the study area are analyzed for water abstracted from three wells reported to be completed in the Edwards (Fig. 1.7A).

Major Anions

Antlers groundwater contains higher average [SO_4^{2-}] than does Edwards groundwater (Fig. 1.8). In the Antlers, [SO_4^{2-}] ranges from 2 to 3,020 mg/L and averages 356 mg/L, whereas [SO_4^{2-}] in the Edwards ranges from 0 to 2,220 mg/L and averages 59 mg/L (TWDB, 2008). Occurrences of groundwater that exceed [SO_4^{2-}] guidelines (250 mg/L) established for drinking water by the U. S. Environmental Protection Agency (EPA, 2006) are widespread.

Of particular importance to the interpretations that follow, the Antler water has a larger fraction of sulfate relative to its total anion and TDS content than Edwards groundwater does (Fig. 1.7, A1.1). In the Antlers SO_4/anions ranges from 0.007 to 0.91 and averages 0.36, whereas SO_4 /anions in the Edwards ranges 0 to 0.93 and averages 0.088 (TWDB, 2008).

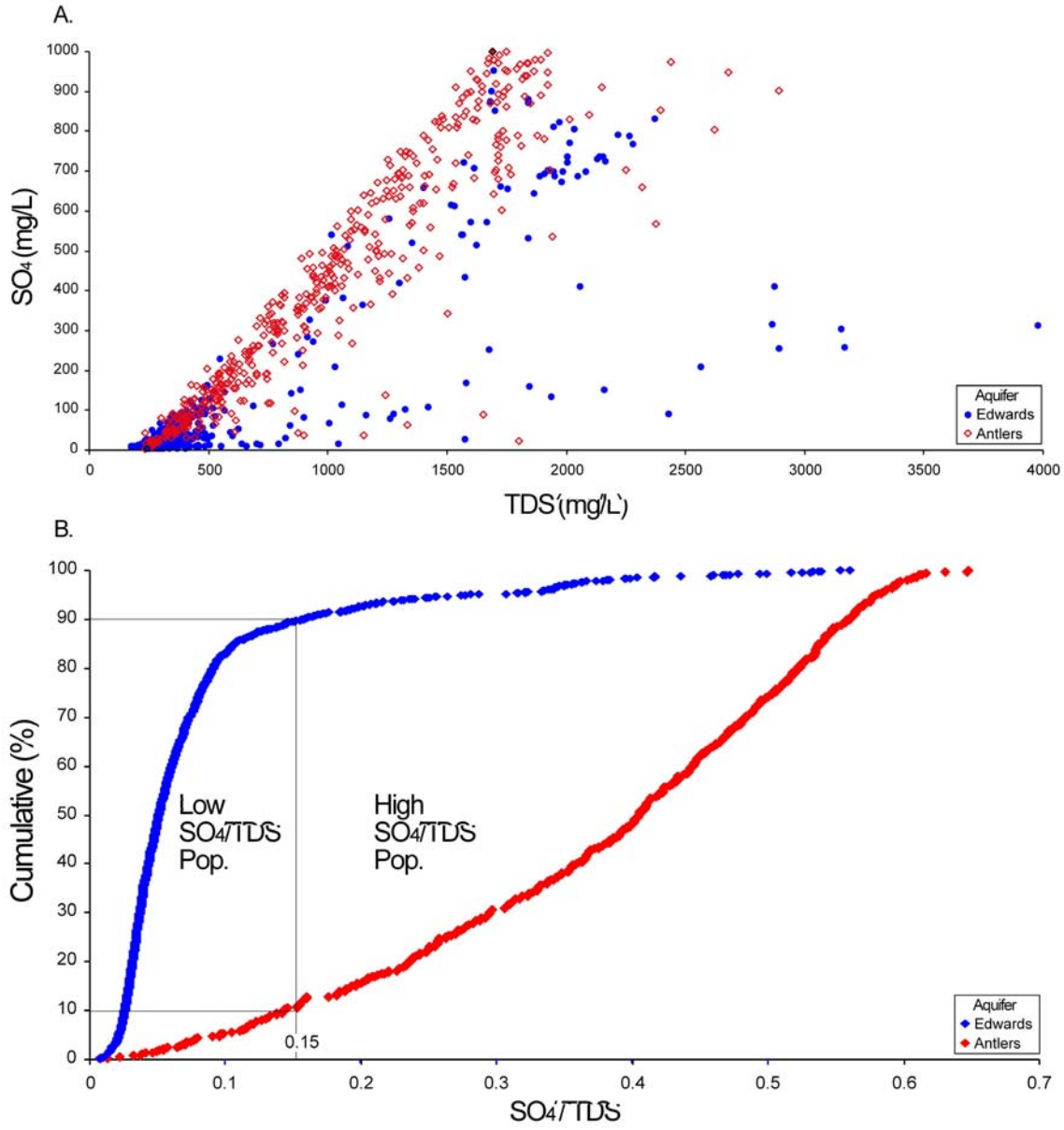

Figure 1.7. Relationships between [SO_4^{2-}] and [TDS] in groundwater for counties from which recent samples also were acquired by writer: A) shows two major linear trends that suggest the presence of two populations of groundwater types based on relative proportions of [SO_4^{2-}] to waters that indicates overall low SO_4/TDS for Edwards waters and overall higher SO_4/TDS for Antlers waters. A value of SO_4/TDS = 0.15 is used to divide the data into high- and low- SO_4/TDS populations where 90% of Edwards samples are classified as low-SO_4/TDS and 90% of Antlers samples are classified as high-SO_4/TDS. Distribution in a) of high SO_4/TDS Edwards and many of the Antlers data to right of the pronounced linear trend in Antlers data may reflect mixing of Antlers and low-SO_4/TDS Edwards waters. Data is based on analyses performed since1959 (TWDB, 2008).

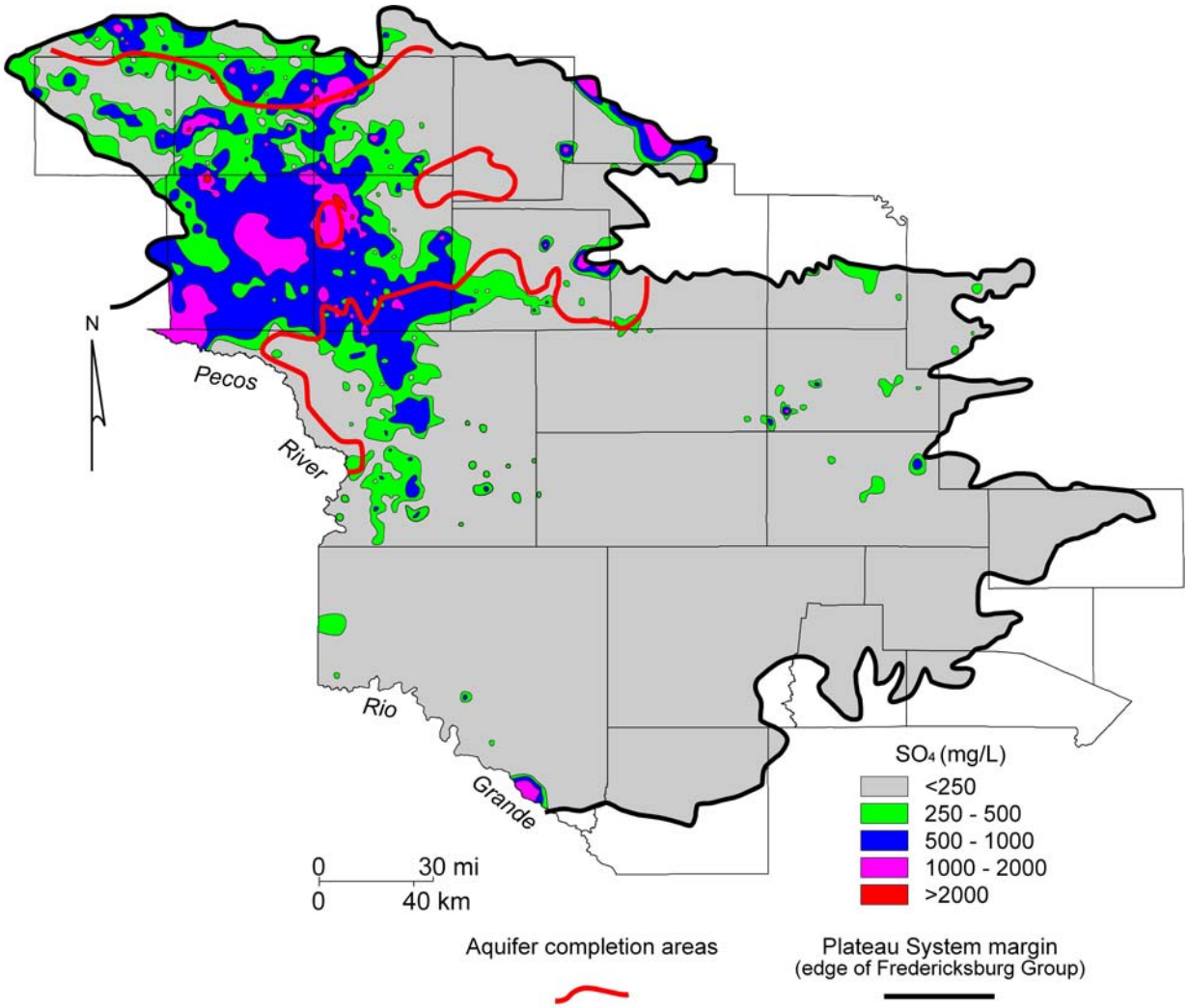

Figure 1.8. Distribution of $[SO_4^{2-}]$ in Plateau groundwater. Values greater than 250 mg/L exceed secondary EPA (2007) guidelines for drinking water. See Figure 1.6 for explanation of aquifer completion areas. Antlers wells show the highest overall $[SO_4^{2-}]$. Elevated $[SO_4^{2-}]$ in Edwards wells is interpreted to record mixing between Edwards and Antlers groundwater. Data from TWDB (2008).

Antlers groundwater, on average, contains a slightly lower [HCO_3^-] than Edwards groundwater does. In the Antlers [HCO_3^-] ranges from 51 to 812 mg/L and averages 257 mg/L, whereas [HCO_3^-] in the Edwards ranges from 88 to 597 mg/L and averages 274 mg/L (TWDB, 2008).

Antlers groundwater, on average, contains a greater [Cl^-] than Edwards groundwater does. In the Antlers [Cl^-] ranges from 2 to approximately 16,300 mg/L and averages approximately 200 mg/L, whereas [Cl^-] in the Edwards ranges from 2 to 4,900 mg/L and averages approximately 60 mg/L (TWDB, 2008).

Isotopes

Antlers groundwater exhibits higher $^{87}Sr/^{86}Sr$ values than does Edwards groundwater (A1.1). $^{87}Sr/^{86}Sr$ ranges from 0.70849 to 0.70877 and averages 0.70866, whereas $^{87}Sr/^{86}Sr$ for Edwards samples ranges from 0.70769 to 0.70850 and averages 0.70806.

Antlers groundwater exhibits, on average, more depleted $\delta^{18}O$ and δD values than does Edwards groundwater (A1.1, Fig. 1.9). $\delta^{18}O$ for Antlers groundwater samples collected for this study range from -8.8‰ to -4.4‰ and average -6.4‰, whereas $\delta^{18}O$ for Edwards samples range from -7.5‰ to -4.2‰ and average -5.1‰. δD for Antlers groundwater samples collected for this study range from -65.1‰ to -34.2‰ and average -45.8‰, whereas δD for Edwards samples range from -52.8‰ to -31.7‰ and average -36.3‰.

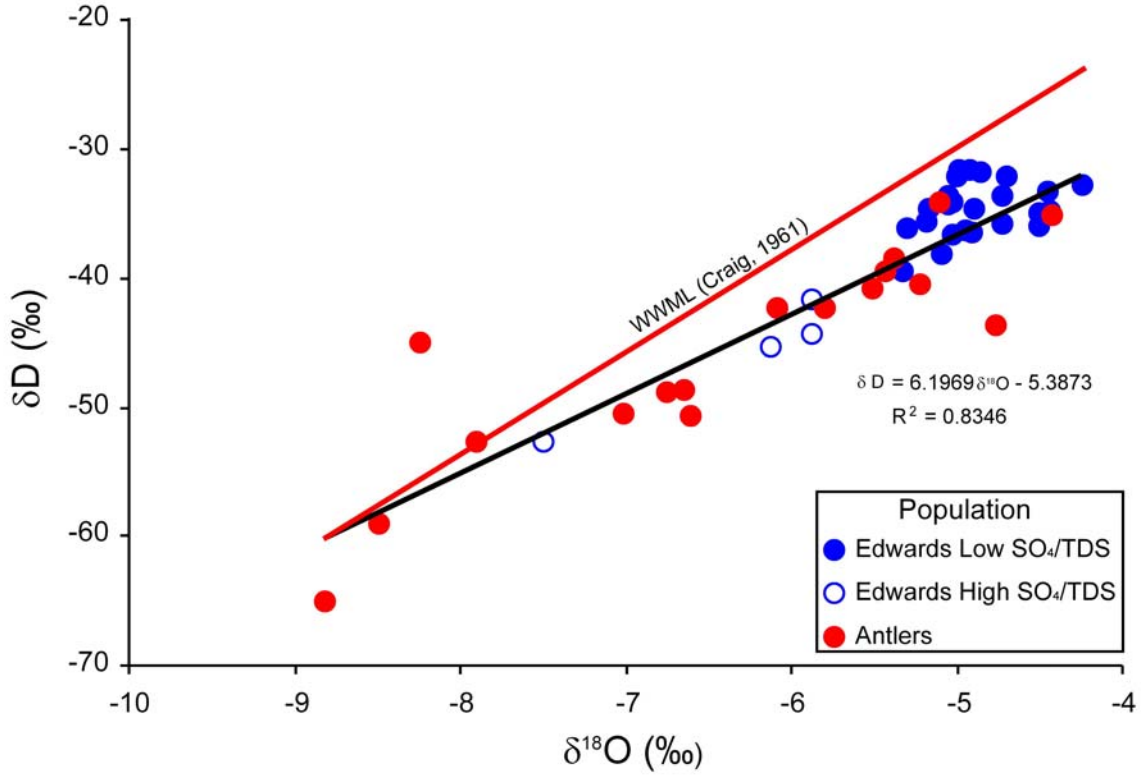

Figure 1.9. Relationships between δD and $\delta^{18}O$ in samples collected for this study. Also shown are the regression lines for the samples and for the worldwide sample data analyzed by Craig (1961). The divergence of the Plateau samples from the trend shown by the worldwide data suggest greater overall evaporation for the semi-arid Plateau recharge than for the worldwide samples. Note the overall greater depletion of heavy isotopes for the Antlers and high-[SO_4] Edwards waters than for the low- SO_4/TDS Edwards waters. Data suggests 1) mixing between less depleted water with more depleted water to produce water in the mid-range of the trend, or 2) recharge of each water in sample set under different temperature conditions.

Antlers groundwater exhibits, on average, lower activities of ^{14}C (pmC) and ^{3}H (tritium) than Edwards groundwater does (App. 1.1, Fig. 1.10). PmC for Antlers groundwater samples collected for this study range from 0.044 to 0.505 and average 0.273, whereas pmC for Edwards samples range from 0.071 to 0.703 and average 0.373. Antlers groundwater samples range from <0.1 to 1.23 T.U. and averages 0.27 T.U., whereas Edwards samples range from <0.1 to 3.28 T.U. and averages 0.74 T.U.

Rainwater

For the Edwards Plateau the primary source for rainwater chemistry data is the National Atmospheric Deposition Program (NADP) that analyzes rainwater at Sonora (Sutton County), Texas after every measurable rainfall event. Based on data collected between 1984 and 2007 Table 1.1 summarizes average concentrations of major ions in rain at Sonora. $\delta^{18}O$ is from Pape and others (in press).

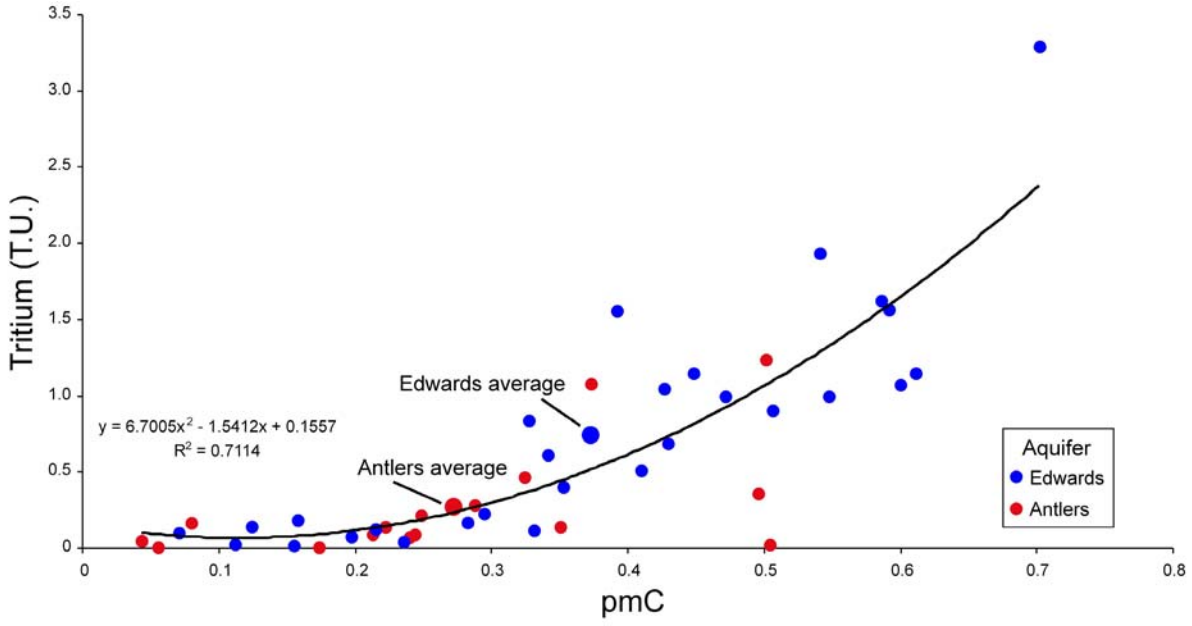

Figure 1.10. Relationships between of pmC and tritium content in Edwards and Antlers groundwater, Plateau aquifer aquifer system. Larger data points indicate average for each aquifer. Oldest water occurs in the Antlers while youngest water occurs in the Edwards. Overlap in ranges for aquifers may indicate local co-mingling of waters between aquifers. Oldest Edwards waters may reflect addition of non-radiogenic carbon from dissolution of carbonate matrix.

Table 1.1. Average composition of rainfall at Sonora, TX:

Ion	Concentration (mg/L)
Ca^{2+}	0.33
Mg^{2+}	0.03
K^{+}	0.03
Na^{+}	0.14
NH_4^{+}	0.24
NO_3^{-}	0.72
Cl^{-}	0.21
SO_4^{2-}	1.02
$\delta^{18}O$	-4.9‰

DISCUSSION

Relations Between Salinity and Isotope Composition

There are generally inverse relationship between values of δD, $\delta^{18}O$, and [TDS] in Plateau groundwater (Fig. 1.11). Banner and others (1989) noted similar relationships in saline groundwater in Missouri. These circumstance contrast with studies of saline surface water bodies where increasing salinity generally corresponds with enrichment of heavy isotopes caused by preferential loss of the lighter isotopes during evaporation (e.g. Craig, 1966). An explanation of the depletion of heavy isotopes with increasing Plateau

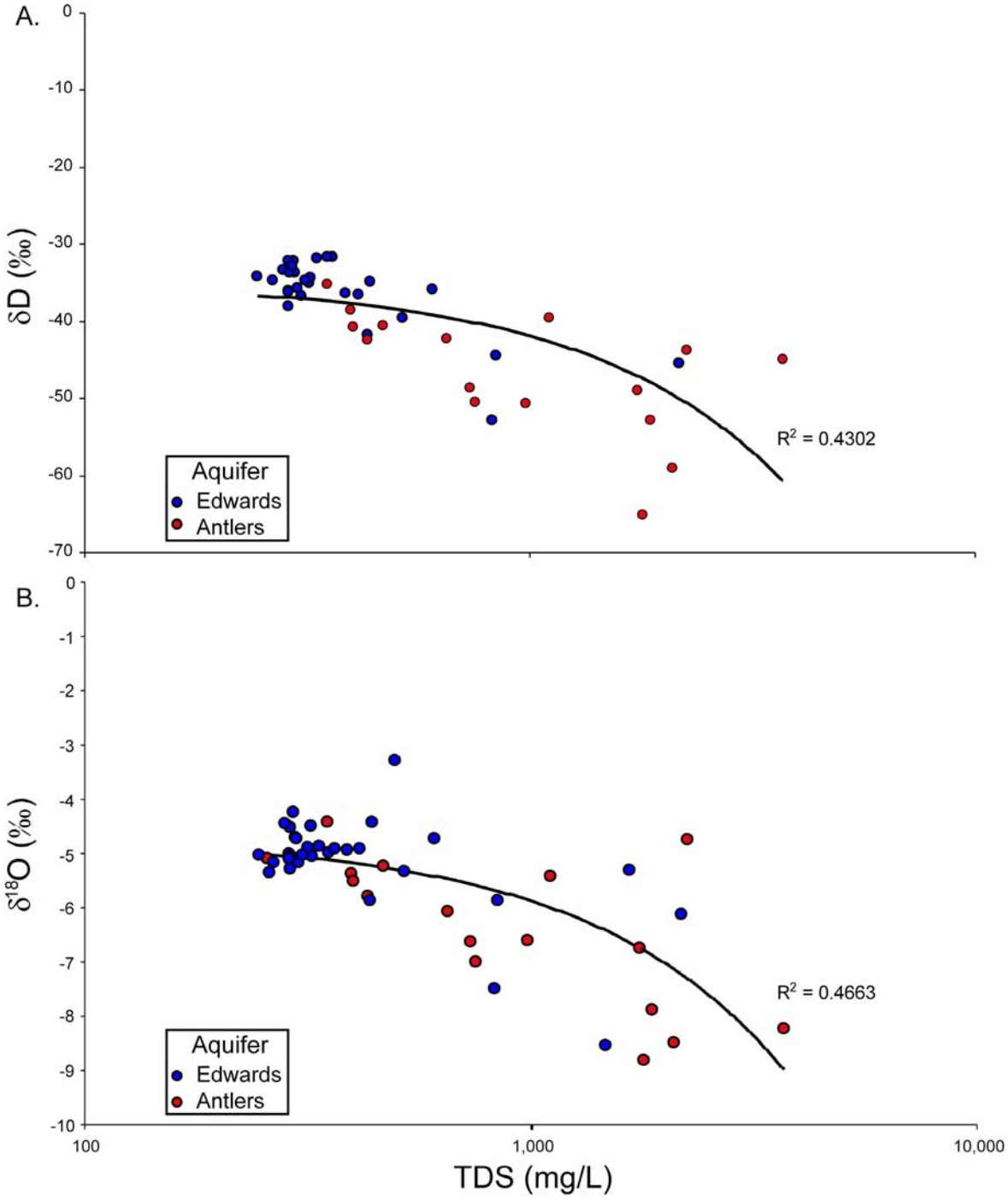

Figure 1.11. Relationship between A) δD, B) $\delta^{18}O$, and [TDS] in Plateau groundwater. Trend suggests that isotope signature reflects cooler climatic conditions during recharge of more saline groundwater, whereas salinity reflects mineral dissolution along flow path. Overall older age of isotopically more-depleted Antlers water (Fig. 1.10) suggests that higher salinity reflects longer residence time.

groundwater salinity is that the isotopic signatures reflect paleo-climatic effects on isotope composition in meteoric recharge, whereby overall older groundwaters were recharged under cooler conditions and have resided in the aquifer for longer times. Longer residence times provided greater opportunity for mineral dissolution, thus higher dissolved loads.

Hydrochemical and Isotopic Variability

Elemental and isotopic variability in Plateau groundwater includes not only varying concentrations of dissolved constituents in water but also varying relative proportions of constituents among themselves. Groundwater variability is three-dimensional and varies temporally. Compositional variability arises from multiple interrelated processes. Reactions between aquifer matrices and resident water are a primary cause of variability. Within individual aquifers the occurrences, relative abundances, and textural characteristics of constituent minerals varies laterally because the original environments of deposition, mineral compositions of sediments, and diagenetic products vary spatially and temporally. Reactions between groundwater and aquifer matrix may be manifested largely in dissolution/precipitation reactions, ion exchange reactions, or both.

Hydro-stratigraphic variability may mark aquifer compositions that vary stratigraphically where discrete stratigraphic intervals may be separated by low-permeability units that inhibit cross-formational mixing of water. The reaction products between groundwater and aquifer along flow paths also change because groundwater evolves chemically during previous reactions. Variability also arises from mixing

between groundwaters of diverse origins and flow paths. Such mixing can occur in areas where fractures promote communication between otherwise segregated elements of an aquifer system. Cross-formational communication through wells that are completed in multiple, otherwise naturally segregated stratigraphic intervals is also common. Studies of hydro-stratigraphic variability ideally should avoid including such wells in the analysis because of difficulties with determining relative contributions for specific aquifers. Finally, it is also important to consider the potential for errors in published data bases where stratigraphic intervals may be misidentified.

Groundwater variability can also arise from variations in the effectiveness of overlying rock to facilitate recharge. Areas with abundant karst may promote rapid recharge whereby recharge may be compositionally similar to rainwater; whereas areas less affected by karst will contain recharge water for longer times and allow greater degrees of chemical reaction between rocks and recharge water. Rainfall may have similar effects where intense events may flush recharge zones rapidly, whereas lower abundances may allow recharge water to reside in soils for longer or evaporate, thus concentrating salts. Protracted residence of recharge in aquifer pockets may promote more extensive reactions with the aquifer matrix.

Climatic conditions and groundwater flow patterns may also change through time, in some cases preserving hydro-compositional legacies from previous environmental conditions in the study area or recording climatic influences in paleo-recharge zones that were distant from the study area. Constituents contributed by recharge under antecedent circumstances affects the composition of water in the modern system where mixing has

occurred between waters of significantly different ages. Compositional variability also may be affected by anthropogenic inputs (e.g., agricultural or industrial contamination) or abstraction intensity where pumping stresses may draw water from areas or stratigraphic intervals that would not flow to the sampling point under natural hydrological conditions.

This paper focuses on one of these processes, cross-formational mixing of waters of significantly different ages and with different origins. The stratigraphic intervals involved are the basal siliciclastic unit of the Plateau system, the Antlers aquifer; and the primary carbonate aquifer unit in the study area, the Fredericksburg/Washita Groups, otherwise known as the Edwards aquifer.

Origins of Plateau System Groundwater Constituents

Major Anions

The most likely source of abundant sulfate to the Plateau system is the Upper Permian subcrop which contains abundant calcium sulfate in the form of regionally extensive evaporite beds. Abundant sulfate found in Dockum Group water (TWDB, 2008) probably also originated in the Permian section. The fluvial-deltaic and shoreface depositional systems of the Antlers sandstone or Dockum sandstone have neither been observed nor interpreted to ever have included evaporites (e.g., Stricklin and others, 1971; McGowen and others, 1979); and the distribution of major Cretaceous evaporite systems in stratigraphically overlying units have been interpreted to have occurred down-dip of areas where sulfate-enriched Antlers and Edwards groundwater is most common (Fisher and Rhodda, 1969). If Cretaceous evaporites were more extensive than previous

workers concluded, dissolution of those units may have provided the groundwater sulfate now observed.

Transmission of sulfate-enriched groundwater from the Permian section into the Plateau system would require a flow system with an upward flow component. The present distribution of hydraulic heads (TWDB, 2008) does not support the upward flow of groundwater from the Permian into the Plateau system. Therefore, ancestral hydraulic conditions must have been different than those present today. The hydrodynamic conditions required to transmit sulfate-enriched water from the Permian up into the Cretaceous section will be discussed later.

The most likely source of the greatest portion of HCO_3^- is dissolution of carbonate in soils of recharge zones and in aquifer carbonate matrix. The Plateau area is mantled by carbonate-rich soils that developed on the ubiquitous, almost totally carbonate strata of the Fredericksburg/Washita Group carapace (Fig. 1.3). Carbonate minerals are common as cement and carbonate rocks are common as minor interbeds in the siliciclastic-dominated Antlers aquifer. Present-day recharge of the Antlers is by precipitation on the overlying Fredericksburg/Washita, so that bicarbonate acquired in route through the Edwards aquifer will eventually enter the Antlers.

Chloride in the Plateau system may have several sub-Plateau system sources that occur in the Plateau aquifers by both natural and anthropogenic processes. Similar to Plateau system SO_4^{2-}, dissolution of Permian halite beds is a potential mechanism for chloride production. For this to be the case the same hydrodynamic conditions that allow upward flow of groundwater would have to be present as would have to be for SO_4^{2-}

transport into the Plateau system from the Permian section. However, maps of [Cl^-] prepared by the writer (not shown) do not display the same geographical patterns as those for sulfate (Fig. 1.8) and indicate that areas with [Cl^-] greater than 20 mg/L generally are centered around apparent point sources that are associated with industrial (e.g., oil and gas) or municipal operations in the region. A few areas where chloride proportions are sufficient to dominate the anion fraction of Plateau groundwater are shown in Figure 1.12. Evidence from average rainwater chemistry in the region suggests that [Cl^-] in most locations, even at very low values, can not be explained solely by the evaporation of rainwater. Examination constituent concentrations (Table 1.1) show that the average SO_4/Cl of Sonora rainwater is 4.77, whereas average SO_4/Cl of Edwards groundwater with [Cl^-]<10 mg/L (TDS from 246 to 338 mg/L) in Sutton County is 0.84. At such low salinities it is unlikely that SO_4^{2-} is being lost by precipitation of gypsum within the aquifer. Therefore, many samples with very low [Cl^-] appear to contain Cl^- from sources other than local rainwater. However, several Edwards samples with low [TDS] do have SO_4/TDS in the range of 4.0 to 5.0, the approximate SO_4/TDS of Sonora rainwater. The freshest of these samples has 242 mg/L TDS, 10 mg/L SO_4^{2-} , and 2 mg/L Cl^-. Based on an average [Cl^-] in Sonora rainwater of 0.22 mg/L (NADP, 2008), this sample may represent evaporative reduction of rainwater volume to approximately10%, which corresponds to an average annual recharge rate of 10%. Evaporation would occur in the soil prior to percolation to the water table. The rate of evaporation generally is anticipated to decrease with depth, with the caveat that evaporation rates would increase at any depth during times of prolonged drought or increases in air temperature. Further, evaporation of

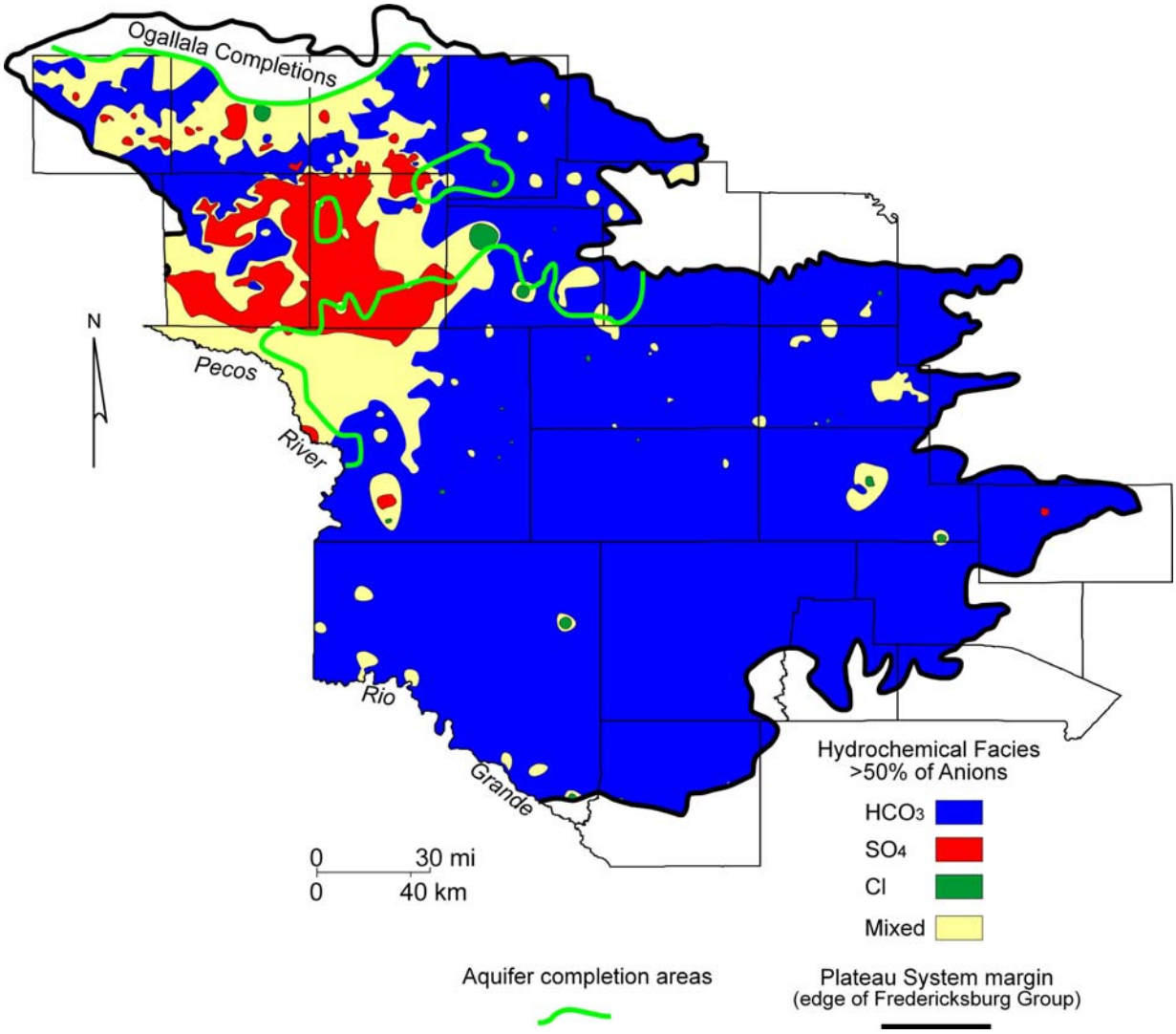

Figure 1.12. Distribution of anion hydrochemical facies based on composition of water exceeding 50% for specified anion. Note highly localized character of Cl^- facies suggesting point sources for Cl^-. See Figure 1.6 for explanation of aquifer completion areas. Data from TWDB (2008).

rain samples in NADP collectors is assumed to be negligible and reported elemental concentrations are assumed to be representative of those of rain prior to any reaction with soil components.

δD and $\delta^{18}O$ Relationships

Depletion of D and ^{18}O in the Antlers relative to the Edwards of up to -32.3‰ and -4.59‰, respectively, suggests recharge under cooler climatic conditions for the Antlers. Overlap in the ranges of δD and $\delta^{18}O$ values for the two aquifers could reflect ranges of recharge temperatures for each aquifer, mixing of waters between aquifers, or both. Figure 1.9 documents the overall isotopic distinctiveness of water from the two aquifers. The figure also shows overlap between δD and $\delta^{18}O$ values for several samples from each aquifer. Based on relationships established by Dansgaard (1964) for temperature effects on isotopic variations in water condensate ($d\delta^{18}O/^oC$ = 0.7‰; $d\delta D/^oC$ = 5.6‰) the recharge temperature for the Antlers sample is approximately 6°C cooler than for the Edwards sample.

The least-depleted value of -4.23‰ for $\delta^{18}O$ is from the Sonora area and corresponds to a calculated average temperature of 13.5°C to 20.6°C, based on the $\delta^{18}O/^oC$ relationship $\delta^{18}Om = 0.695T - 13.6$ (Dansgaard, 1964) and $\delta^{18}Om = 0.521T - 14.96$ (Yurtsever, 1975), where $\delta^{18}Om$ is the mean annual $\delta^{18}O$ of precipitation and T is the average air temperature in °C. The average of this range is about 17°C. By comparison, modern average air temperature in Sonora averages from 17°C to 21°C, averaging 19°C. However, average temperature in Sonora when the peak of precipitation

usually occurs in September is about 17°C (Larkin and Bomar, 1983). The similarities between average temperature derived by averaging the $\delta^{18}O/T$ relationships advanced by Dansgaard and Yurtsever with the measured average temperature recorded during the historically wettest time of the year in Sonora is consistent with the interpretation that the groundwater with $\delta^{18}O = -4.23‰$ is modern. This water has a $\delta^{18}O$ value between the modern values for the Sonora area that range from -5.5‰ to -4.0‰, and average -4.9‰ (Pape and others, in press).

According to Dansgaard (1964) depletion of the heavy isotopes of hydrogen and oxygen can be attributed to either or a combination of four influences including air-mass transit across large expanses of land during which precipitation occurs (continental effect), large volumes of rainfall during which heavier isotopes are preferentially involved in condensation (amount effect), latitude effects whereby rain is generally more depleted isotopically at higher latitudes, and recharge at higher elevations than those where water is sampled (elevation effect).

Lower isotopic values could record cooler paleo-climatic conditions either in the study area, or elsewhere if ancestral recharge areas were different than they are presently. Dutton and Simpkins (1989), using differences is water stable isotope values between the High Plains and Dockum aquifers, proposed that the paleo-recharge area for the Dockum aquifer beneath the High Plains was at a higher elevation than is the modern recharge area. Assuming that elevation differences are entirely responsible for the differences in depletion values for Antlers and Edwards water stable isotopes, then elevation differences are on the order of 1.8 km, based on a $\delta^{18}O$ depletion value of -2.5‰/km (Fontes, 1980).

Given the present average elevation of the Edwards Plateau to be approximately 0.762 km (2,500 ft), the calculated elevation of the paleo-recharge area from which the most depleted Antlers groundwater originated is 0.762 km + 1.8 km = 2.562 km (approximately 8,400 ft). Elevations of this magnitude occur in Otero County, New Mexico, approximately 65 mi (105 km) west of the Pecos River. The surface bedrock geology in Otero County is dominated by Permian strata (Dane and Bachman, 1965) that extends largely into the subsurface toward the east to the Edwards Plateau region. Alternatively, recharge could have occurred at lower elevations where paleo-temperatures were cooler than modern values.

Radiocarbon and Tritium

The radiocarbon and tritium data suggest that the oldest ages are for Antlers water, while the youngest ages are for Edwards water. Overlap in the ranges of pmC and tritium analyzed from the two aquifers could reflect ranges of recharge ages for each aquifer, mixing of waters between aquifers, mixtures of older water with fresher recharge water, or any combination of these processes. The potential contribution of non-radiogenic carbon (^{12}C, ^{13}C) to the groundwater through carbonate-matrix dissolution or oxidation of organic carbon is an issue for interpretation of groundwater age (e.g., Wigley, 1975) whereby overestimates of age can result. The potential for exchange of ^{14}C for non-radiogenic carbon along flow paths (e.g., Pearson, 1992) or acquisition of ^{14}C from sources other than natural soil gases also may be issues in specific cases. The possibility of matrix dissolution may cast greater doubt on the apparent ages of some of the Edwards

waters rather than the ages of Antlers because the Edwards is almost entirely carbonate. Although carbonate-matrix dissolution may be an issue for the interpretation of groundwater ages from pmC in the Plateau system, co-variation in tritium values with pmC values (Fig. 1.10) tends to support the conclusion that, on average, oldest waters in the system occur in the Antlers. If the addition of dissolved non-radiogenic carbon from the carbonate fraction in the aquifer matrix has influenced Plateau system pmC content, then the differences in average age between groundwaters from the two aquifers may be greater than suggested by the data.

The apparent ages of the waters range from 1940 years BP to 23,060 years BP. Although it is beyond the scope of this paper to critically evaluate the absolute age of the sample waters, some reasoning may be helpful for constraining the range of ages for sample waters.

First, it is reasonable to assume that the youngest Edwards water is close to modern (less than 60 years), given the 1) karstified and unconfined character of the aquifer, 2) high abundance of tritium (3.28 T.U.), and 3) a calculated recharge temperature from $\delta^{18}O$ that is approximately equal to the modern air temperature. The apparent age of this sample is 1940 years. Assuming that all the added non-radiogenic carbon was not accounted for by the $\delta^{13}C$ correction, the error in the reported apparent age may be approximately 2000 years, which is the age calculated for the most pmC-rich sample which also contains abundant tritium. At the other end of the age spectrum is the Antlers water reported to have an apparent age of 23,060 years. The sample contains no measurable tritium, thus, no significant fraction of water less than about 60 years old. The

Antlers aquifer is probably confined, based on calculations of storativity from aquifer tests (TWDB, 1969). Assuming a 2000-year error in the calculated age, and assuming that this sample has been isolated from significant input of younger water, a corrected age for the Antlers sample is 21,060 years. Therefore, by integrating water stable isotope data and radiogenic data it is proposed that the recharge temperatures of the Plateau system have raised 6^{o}C over approximately 21,000 years. If the Antlers sample contains some fraction of water less than 21,000 years old then some of the water was recharged at an even earlier time. Even if the proposed estimate of groundwater age is nearly two times the actual age, recharge of the Antlers sample probably occurred during the later part of the Pleistocene.

Evidence for Multi-Component Mixing

The best explanation for the distribution of sulfate, stable isotopes, and radiogenic isotope in groundwater of the Plateau system is multiple-component mixing between three end-member water types: 1) modern evaporated rainwater, 2) low-SO_4/TDS Edwards groundwater, and 3) Pleistocene-age high-SO_4/TDS Antlers groundwater.

Six lines of evidence support a three-component mixing model for Plateau system groundwater, including relationships between 1) [SO_4^{2-}] and [TDS], 2) δD and δ^{18}O, 3) δD, δ^{18}O and SO_4/TDS, 4) strontium isotopes and [Sr^{2+}], 5) strontium isotopes, δD, and δ^{18}O, and 6) geographical distributions of SO_4/TDS values.

$[SO_4^{2-}]$ and [TDS] Relationships

Relationships between $[SO_4^{2-}]$ and [TDS] are depicted in Figure 1.7. Two approximately linear trends are evident. One trend contains samples whose SO_4/TDS is greater than approximately 0.15 (high-SO_4/TDS population), whereas another trend contains samples whose SO_4/TDS is less than 0.15 (low-SO_4/TDS population). Ninety percent of Antlers samples populate the high-SO_4/TDS population trend, whereas 90% of the Edwards samples populate the low-SO_4/TDS trend (Fig. 1.7B). Within the high-SO_4/ TDS population, Antlers water has the highest $[SO_4^{2-}]$ and [TDS]. The most saline water in the high-SO_4/TDS population is from the Antlers with 1,751 mg/L TDS and 1000 mg/L SO_4^{2-}. Water with high-SO_4/TDS and elevated [TDS] is proposed to be one of the end members within the multi-component mixing model. Within the low-SO_4/TDS population Edwards samples have the highest $[SO_4^{2-}]$ and [TDS]. The most saline water in the low-SO_4/TDS population is from the Edwards with 3,981 mg/L TDS and 311 mg/L SO_4^{2-}. Water with low-SO_4/TDS and high [TDS] is proposed to be another of the end members within the multi-component mixing model. The two trends converge near the dilute Edwards sample proposed above as possibly evaporated rainwater (242 mg/L TDS and 10 mg/L SO_4^{2-}). Dilute, evaporated rainwater is proposed to be the low salinity end member within the multi-component mixing model.

Distribution of individual data in the space bounded by ideal end-member mixing lines based on the proposed end members may represent mixtures of waters from each of the SO_4/TDS-based populations. These examples show systematic geographical

distributions which will be demonstrated later. In particular, the associations of Antlers and Edwards data near the high-SO_4/TDS trend (Fig. 1.7A) but with overall lower

SO_4/TDS values in the population suggest an Antlers-dominated mixture of Antlers and Edwards waters. If the mixing model is correct and all the end members are identified, then all the data should be distributed within a triangular envelope whose vertices are defined by the end members. For an end-member model to account for all the Plateau system data end-member components are required that have not been sampled. A mixing envelope is required that has a low-SO_4/TDS end member that has a [TDS] of approximately 5,000 mg/L and [SO_4^{2-}] of less than 10 mg/L; and a high-SO_4/TDS end member with a [TDS] of approximately 2,100 mg/L and [SO_4^{2-}] of approximately 1,300 mg/L. The required dilute, precipitation-like end member would have a [TDS] of less than 3 mg/L and [SO_4^{2-}] of approximately 1 mg/L.

δD and $\delta^{18}O$ Relationships

Relationships between $\delta^{18}O$ and δD analyzed for samples collected for this study are depicted in Figure 1.9. Most of the Plateau system data are distributed along a trend that probably records relatively more evaporation than was recorded by samples used to define the worldwide meteoric line published by Craig (1961). An evaporation trend is a reasonable expectation for semi-arid areas such as the Edwards Plateau where evaporation rates are relatively high. Within the data the Antlers occupies the space that records greater heavy-isotope depletion, whereas the Edwards low-SO_4/TDS samples occupy the space that records less heavy-isotope depletion. The high-SO_4/TDS Edwards

samples show intermediate degrees of depletion. This distribution suggests that the high-SO_4/TDS Edwards samples are mixtures of high-SO_4/TDS Antlers waters low-SO_4/TDS Edwards waters.

$\delta^{18}O$, δD, and SO_4/TDS Relationships

Relationships between $\delta^{18}O$ and SO_4/TDS for samples collected during this study are depicted in Figure 1.13. Most of the Edwards aquifer samples cluster between $\delta^{18}O$ values of -4‰ and -5.5‰, and SO_4/TDS values of 0 and 0.1, whereas all of the Antlers samples have greater SO_4/TDS values and about 70% of them are more depleted in ^{18}O.

The data that trends closest to the regression line represent co-variation in those samples of $\delta^{18}O$ and SO_4/TDS and indicate overall cooler recharge temperatures for the high-SO_4/TDS groundwater population. High-SO_4/TDS Antlers samples that show degrees of depletion similar to the low-SO_4/TDS Edwards samples are similar in $\delta^{18}O$ values of Ogallala samples sampled in the same county. The Ogallala overlies the Plateau system and mixing of recharge that is transmitted through the Ogallala may mix with Antlers water locally, thus affecting locally the water-stable-isotope composition of water abstracted from the Antlers aquifer. The high-SO_4/TDS Edwards samples occur along the trend occupied by most of the high-SO_4/TDS Antlers samples, thus suggesting a mixing relationship for these samples between high-SO_4/TDS Antlers and low-SO_4/ TDS Edwards waters.

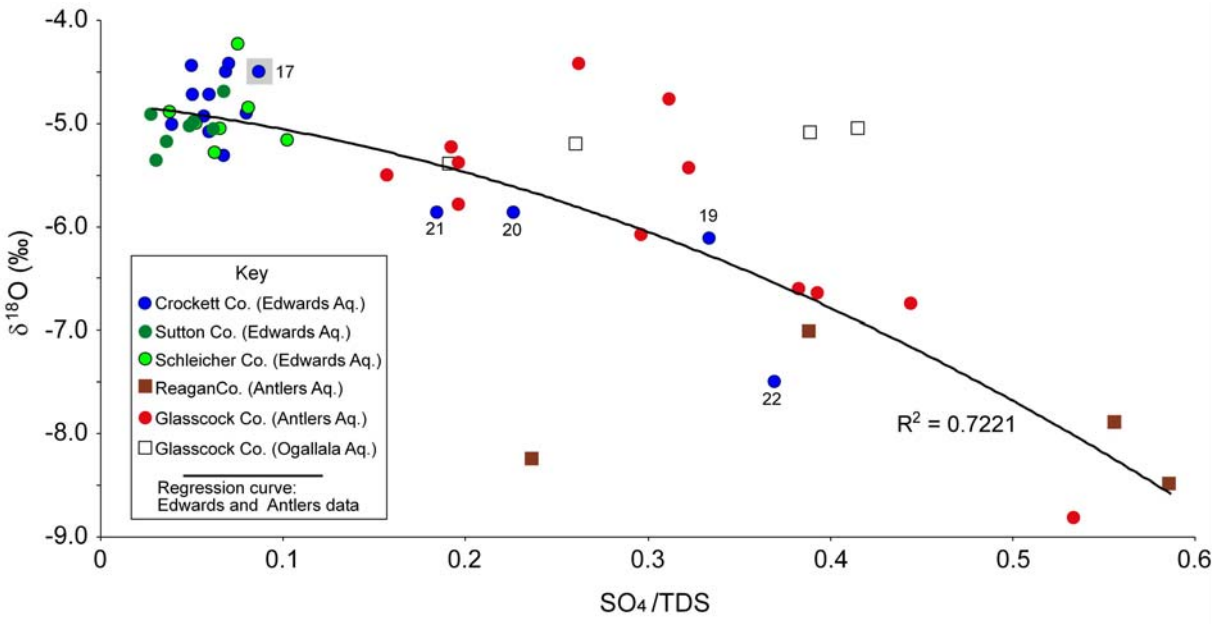

Figure 1.13. Relationships between SO_4/TDS and $\delta^{18}O$ for Edwards, Antlers, and Ogallala groundwater sampled for this project. Note greater overall depletion in $\delta^{18}O$ for Antlers and several Edwards samples (19 to 22; A1.1) that correspond to relative enrichment in $[SO_4^{2-}]$. These same Edwards samples show trend toward Antlers cluster in Figure 1.11, thus suggesting that they record mixing between Edwards and Antlers end-members, respectively. Also shown are Ogallala samples from Glasscock County. Deviation of several Glasscock County Antlers waters from the regression curve, thus showing enrichment of $\delta^{18}O$ compared to other Antlers with similar SO_4/TDS, may indicate mixing between some of the Antlers waters with Ogallala water.

Relations Between $^{87}Sr/^{86}Sr$ and Sr Concentration

Relationships between $^{87}Sr/^{86}Sr$ and [Sr] for samples collected for this study are depicted in Figure 1.14. All of the low-SO_4 /TDS samples have $^{87}Sr/^{86}Sr$ less than or equal to 0.70845, whereas all of the Antlers samples have $^{87}Sr/^{86}Sr$ greater than or equal to 0.70849 and occur in the upper left part of the graph. The pattern of data distribution is somewhat predictable when siliciclastic-dominated (higher $^{87}Sr/^{86}Sr$) and siliciclastic-poor carbonate (lower $^{87}Sr/^{86}Sr$) rock analyses are plotted on the same graph. The pattern suggests the presence of a high-[Sr]/low $^{87}Sr/^{86}Sr$ carbonate end member, a high-[Sr]/high $^{87}Sr/^{86}Sr$ end member, and a low-[Sr]/high $^{87}Sr/^{86}Sr$ end member. Work performed in Lower Cretaceous carbonate aquifers in central Texas by Musgrove and Banner (2004) indicates that low-[Sr]/high $^{87}Sr/^{86}Sr$ end member may be soil water where relatively little carbonate has been dissolved (thus, low [Sr]) and the soil has a significant siliciclastic fraction (thus elevated $^{87}Sr/^{86}Sr$). Similar to the three end-member mixing envelope suggested for the Plateau system by SO_4/TDS relationships (Fig. 1.7A), a triangular envelope could be constructed for the strontium isotope data. If such a mixing model is valid it would necessitate identifying an end member with a somewhat higher $^{87}Sr/^{86}Sr$ value and higher [Sr]; and an end member with somewhat a lower $^{87}Sr/^{86}Sr$ value and higher [Sr] that are not represented in the present sample set. Considering the small number of available data, non-representation of end members should be expected.

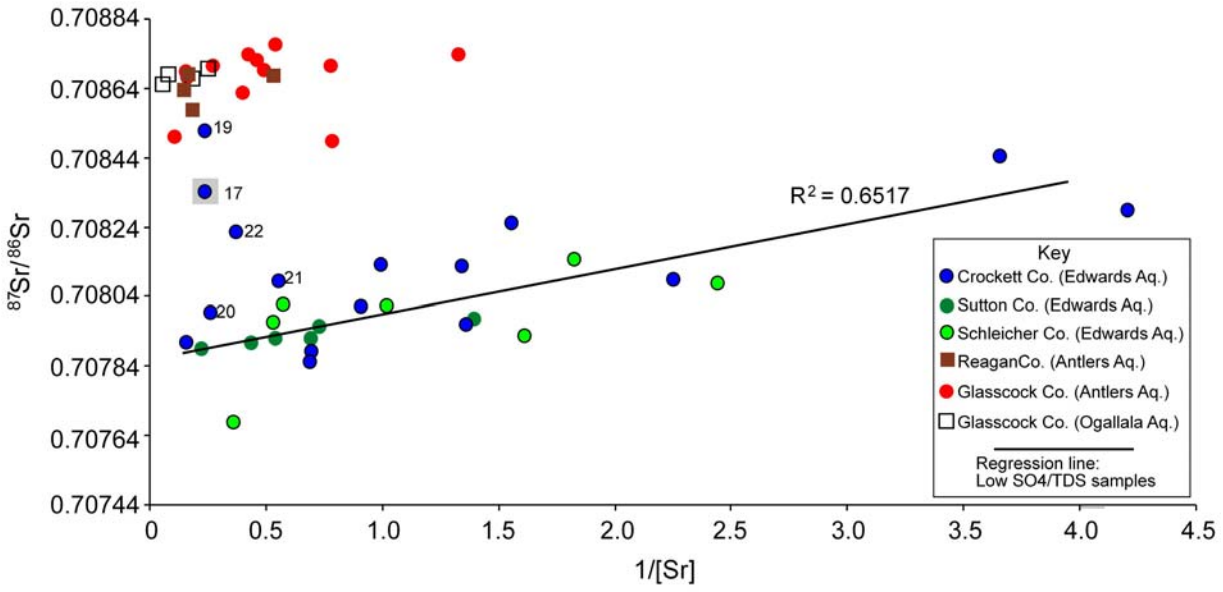

Figure 1.14. Relationships between [Sr^{2+}] and $^{87}Sr/^{86}Sr$ for Edwards, Antlers, and Ogallala groundwater sampled for this project. Numbered high-SO_4/TDS Edwards samples (19 to 22; Table 1.1) show trend toward Antlers cluster suggesting that they record mixing between Edwards and Antlers end-members, respectively. Trend shown in for most Edwards samples suggests mixing between 1) low-[Sr] water with elevated $^{87}Sr/^{86}Sr$ and 2) higher-[Sr] water with lower $^{87}Sr/^{86}Sr$, respectively. Gray square marks a sample (17; A1.1) for which Sr-isotope value suggests a significant fraction of Antlers water, whereas its low SO_4/TDS and elevated $\delta^{18}O$ values do not.

$^{87}Sr/^{86}Sr$ and $\delta^{18}O$ Relationships

The relationships between $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ in groundwater samples collected for this study are shown in Figure 1.15. Data distribution in $^{87}Sr/^{86}Sr$-$\delta^{18}O$ space enables grouping of aquifer-specific data into distinct and generally separate fields and suggests that mixing between waters with different origins is the overriding control on isotope composition . Antlers groundwaters group mainly in the part of the graph where $^{87}Sr/^{86}Sr < 0.7084$, but the range of $\delta^{18}O$ values is the greatest of any aquifer (from approximately -9‰ to -4‰). Ogallala groundwaters have the greatest $^{87}Sr/^{86}Sr$ values (greater than 0.7086) but the narrowest range of $\delta^{18}O$ values (from -5.5‰ to -4.5‰). Edwards waters have the greatest range of $^{87}Sr/^{86}Sr$ values (from 0.7077 to 0.7085) but the second narrowest range of $\delta^{18}O$ values (from -5.2‰ to -4.2‰). A group of Edwards waters characterized by elevated SO_4/TDS values group within $^{87}Sr/^{86}Sr$ range of from 0.7080 to 0.7085 and $\delta^{18}O$ range of from -7.5‰ to -5.5‰. Distribution of these data suggests that Sr-isotope and $\delta^{18}O$ variations are controlled mainly by mixing between groundwaters from the separate aquifers rather than hydrochemical evolution via water-rock interaction (Fig. 1.15). These findings are similar to modeling results produced by Banner and others (1989) during studies of saline groundwater in Missouri.

Data distribution in Figure 1.15 suggests that groundwater from the Ogallala aquifer, stratigraphically the uppermost of the aquifers considered in this study, is contributed to the underlying Antlers aquifer in some areas where the resulting Antlers groundwater is a mixture of down-flowing Ogallala water with elevated $\delta^{18}O$ values and lower-$\delta^{18}O$ water more generally characteristic of the Antlers in areas that are not

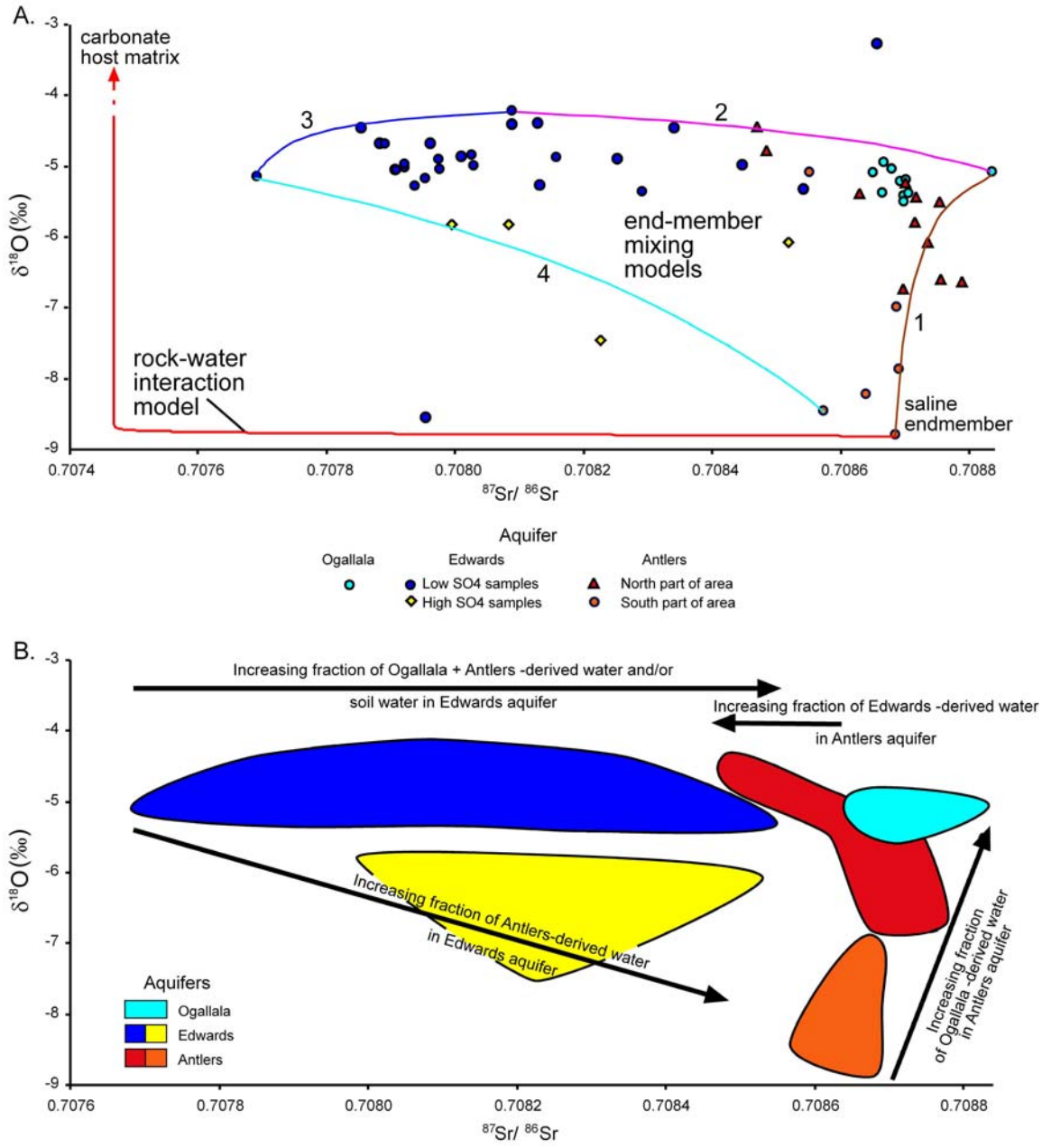

Figure 1.15. Relationships between $^{87}Sr/^{86}Sr$ and $\delta^{18}O$ for Edwards, Antlers, and Ogallala groundwater sampled for this project: A) data points for water isotope analyses (color coded by aquifer), and B) simplified diagram after A) showing generally separate value ranges characterizing groundwaters from different aquifers and interpretations of mixing relationships. The spread of data may be explained as the result of mixing between multiple end-members with representatives in each of the aquifers (several proposed by models 1 through 4). Also shown is a rock-water interaction model (Rokwat) that reacts water from the Antlers aquifer with a Lower Cretaceous carbonate rock representative of those found in central Texas. Rock Sr-isotope data from Koepnik and others (1985); rock $\delta^{18}O$ assumed to be -5 ‰.

overlain by the Ogallala. Trends within the Ogallala-Antlers-mixed water suggest that recharge through the overlying Edwards is mixing with the elevated-$^{87}Sr/^{86}Sr$ Ogallala-influenced Antlers water to produce Antlers water with lower values of $^{87}Sr/^{86}Sr$ than is characteristic of most of the Antlers samples. Trends within the Edwards waters suggest that mixing with Ogallala-influenced Antlers water produces Edwards water with elevated $^{87}Sr/^{86}Sr$ values. Alternatively, local elevation in Edwards-groundwater $^{87}Sr/^{86}Sr$ may reflect influx of soil-water that is enriched in radiogenic Sr during residence in siliciclastic-bearing soils that preceded percolation to the phreatic zone (Nance, this volume).

Geographical Distributions of SO_4/TDS

The geographical distribution of Edwards SO_4/TDS values for three contiguous counties in the study area is shown in Figure 1.16. On this map SO_4/TDS values greater than 0.15 correspond to the high SO_4/TDS population and are similar to 90% of the Antlers waters in SO_4/TDS values; whereas values less than 0.15 correspond to the low-SO_4/TDS population. The map shows a pattern of very elevated SO_4/TDS values in central and north-central Crockett County. Away from this area SO_4/TDS values generally decrease incrementally with distance to the lowest values in Sutton County. Based on the preceding discussions of multi-component mixing it is reasonable to propose that the map patterns in Figure 1.16 reflects declining fractions of Antlers-derived waters in the mixtures as distance increases from the area of greatest SO_4/TDS. Superimposed on the overall pattern of increasing sulfate depletion with distance from

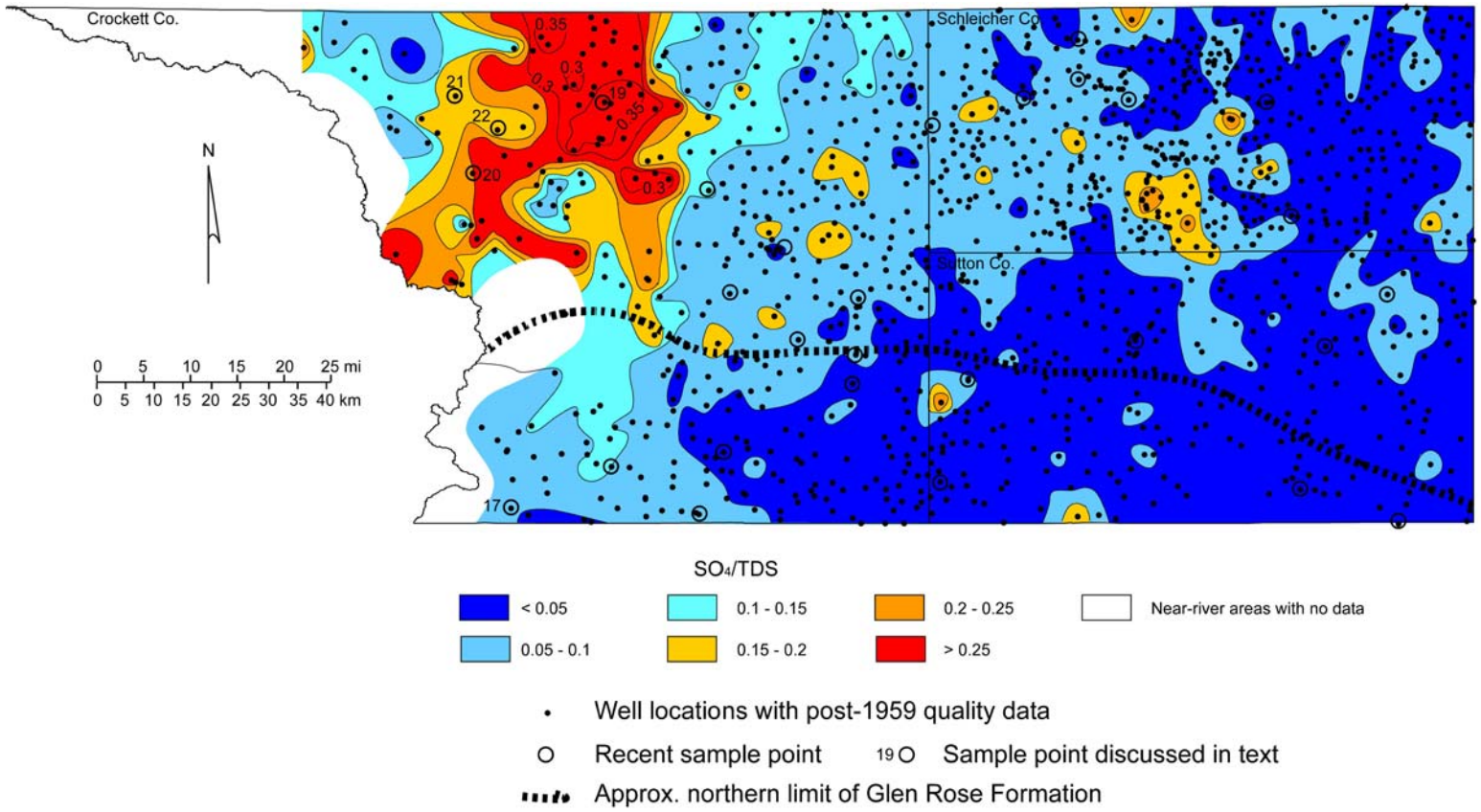

Figure 1.16. Distribution of Edwards groundwater SO_4/TDS. Also shown is published approximate northern boundary of the Glen Rose Formation (Rose, 1972), samples recently collected for this study, and sample numbers for several recent samples that are discussed in text. Waters showing SO_4/TDS of greater than 0.15 (light orange to red) are interpreted to be members of the high-SO_4/TDS population shown in Figure 1.7B. Waters with elevated SO_4/TDS show isotopic similarities to Antlers water sampled elsewhere in the area. Data from TWDB (2008).

central Crockett County are local deviations where elevated sulfate occurs in areas that are generally characterized by lows SO_4/TDS. Some of the deviations from this pattern are elevated SO_4/TDS values reported from isolated locations and may record short-term hydrochemical conditions responding to climatic conditions (e.g., drought) at the time of sampling. However, other interruptions in the regional trend (e.g., south-central Schleicher and north-central Sutton Counties; north-central to south-central Crockett Counties) are defined by numerous data developed from analyses of samples collected at significantly different times and suggest systematic hydrogeological controls. One of these controls is probably geographically variable recharge efficiency whereby some areas are more readily flushed by modern recharge than others (Nance, this volume).

Summary

The data compiled for this study documents five critical observations and associated conclusions that constrain interpretation of the flow systems in the Plateau aquifer system:

1) Plateau system groundwater hydrochemistry and isotope composition indicates the presence of two stratigraphically-based and one modern-precipitation-based end-member water types. These end members originate in the Antlers sandstone aquifer, Edwards carbonate aquifer, and as precipitation-recharge at the Plateau land surface, respectively.

2) The Antlers end-member water type is more saline, more sulfate rich, has higher $^{87}Sr/^{86}Sr$, lower $\delta^{18}O$ and δD, and is older than the Edwards end-member water.

3) The most likely origin of groundwater sulfate that is presently so abundant in the Plateau system is calcium sulfate evaporite in the Permian section that underlies the Plateau system.

4) A mechanism for upward paleo-flow of groundwater through the Permian and Triassic sections is required to account for elevated sulfate in the Edwards aquifer. Presently, hydraulic head distributions promote downward flow.

5) The four end-member waters mix in varying proportions that show systematic geographical patterns. The proportion of the Antlers end member in Edwards aquifer groundwater decreases generally with distance from an area of highest sulfate concentrations in north-central Crockett County. Local and systematic deviations occur in the regional distribution pattern of groundwater sulfate.

A primary issue for understanding flow systems that lead to the present hydrochemical character of the Plateau aquifer system is the source of abundant SO_4^{2-}. There is no evidence that the Cretaceous or Triassic System previously contained sufficiently abundant sulfate over or up dip of the focus area to account for the widespread occurrences of sulfate hydrochemical facies. If groundwater sulfate in the Plateau system was ultimately sourced from dissolving Permian evaporite then groundwater paths would have to have been upward through the Permian and Triassic sections into the Cretaceous section, including the uppermost Cretaceous strata still present. Although present hydraulic conditions appear not to promote upward flow into the Edwards aquifer, this may not have always been the case. Dutton and Simpkins (1989) proposed that stream incision produced the present course of the river (Fig. 1.1),

that its redirected drainage intercepted paleo-flow paths, and that the present valley system now intercepts eastward flow that previously would have recharged the Dockum aquifer in the Texas Panhandle. This proposition is supported by more recent work (Wisniewski and Pazzaglia, 2002) who reason from geomorphic evidence that, prior to the Pleistocene, the Pecos River flowed west to east from its headwaters in the Southern Rocky Mountains of northern New Mexico. Subsequently, dissolution of Permian halite created north-south-trending valleys that redirected the flow of the Pecos toward its present southerly course through south-central New Mexico and into Texas. If true, part of this process is reasonably hypothesized to be redirection of previous west-to-east groundwater flow paths that would have transmitted recharge from the Southern Rocky Mountain area into the Edwards Plateau.

Recharge of the Plateau system, with significant amounts of water precipitated at higher elevations than those presently recharging the system, is consistent with the low δD and $\delta^{18}O$ values of many of the Antlers groundwater samples. Present elevations in most of New Mexico west of the Pecos River are greater than 4,500 ft (1,375 m) above msl, which are at least 1,500 ft higher than the elevation of the base of the Edwards even in the more up dip parts of the Edwards Plateau (Fig. 1.5).Over large expanses of eastern New Mexico, both east and west of the Pecos River, Permian rocks are near the land surface and there is abundant evidence of evaporite dissolution associated with land surface subsidence in the Permian Basin region of Texas and New Mexico (e.g., Gustavson and others, 1980; Baumgardner and others, 1982). With recharge areas located at elevations greater than 1,500 of feet above the Edwards system coupled with

occurrences of Permian evaporite-bearing strata near land surface and confinement of the sub-Edwards hydrogeological units in the Edwards Plateau, there would have been sufficient potential for transmitting sulfate-enriched recharge into the base of the Plateau system and up into the Edwards aquifer.

Attendant with Pecos River incision east-directed flow was intercepted by the Pecos River valley, causing the reconfiguration of the previous hydraulic head distributions and reduction of head differentials that promoted recharge of the Plateau system from the west and upward flow into the Edwards Plateau.

Presently, recharge of the Plateau system is dominantly from precipitation onto the Edwards Plateau as runoff enters normally dry streambeds (Nance, this volume). Comparisons of hydraulic head between the few Antlers and Edwards wells that are near each other suggest that head differentials do not support the potential for intense upward flow, although reports indicate water levels locally do rise somewhat in wells when the base of the Edwards is penetrated and the well contacts Antlers groundwater (White, 1968). Whereas upward-directed groundwater flow might have characterized the Plateau if a portion of its recharge originated in the more elevated terrain to the west during the Pleistocene, downward-dominated flow presently dominates. This redirected flow regime promotes dilution by modern recharge of the sulfate-rich groundwater that was transmitted to the Plateau system during the latter part of the Pleistocene. The general pattern of SO_4/TDS decrease towards the east probably reflects the increase in mean annual rainfall (Fig. 1.2) in the same direction, attendant increase in recharge rates on the karsted surface of the Fredericksburg/Washita Group, and dilution by low-SO_4 recharge.

Local systematic deviations from the regional SO_4/ TDS distribution pattern reflect local hydrogeological influences. For example, the trend of elevated SO_4/TDS from northwest Schleicher County through north-central Sutton County is located upon and along the topographic divide of the Edwards Plateau where there occurs the youngest, overall lowest permeability Cretaceous strata and soils in the study area (Nance, this volume). Similarly, much of the area of elevated SO_4/ TDS in Crockett County underlies a cap of Upper Washita Group strata. Close comparison of Figures 1.3 and 1.16 reveals many similarities between patterns of elevated SO_4/ TDS and the presence of Upper Washita strata. These are areas where the water table is farthest from the land surface, and where soils with the lowest permeability occur. These factors probably retard recharge rates along the divide to the Plateau system (Nance, this volume).

On a more regional scale, the Antlers contains markedly dissimilar groundwater to that in the Edwards with qualities that strongly suggest contact with Permian evaporite. A reasonable explanation is that recharge through the Edwards to the Antlers is largely inhibited by low-permeability strata at the base of the Edwards. Therefore, recharge to the Antlers is limited largely to areas where it is directly overlain by the Ogallala aquifer (Fig. 1.4) and dilution of previously emplaced Permian-sourced groundwater is inhibited.

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CHAPTER 2

GEOLOGIC AND CLIMATIC CONTROLS ON MAGNESIUM-CALCIUM RATIOS, RELATIONS TO GROUNDWATER AGE, AND APPLICATIONS TO RECHARGE-ZONE EVALUATION IN THE EDWARDS AQUIFER, EDWARDS PLATEAU, TEXAS

ABSTRACT

The Edwards aquifer of the Edwards-Trinity (Plateau) aquifer system supplies fresh water to most of the sub-humid to semi-arid 23,400 sq. mi. (60,606 sq. km.) Edwards Plateau in West-central and West Texas. Although Ca-HCO_3 hydrochemical facies are dominant, concentrations of Ca^{2+}, HCO_3^-, Mg^{2+}, NO_3^-, and activities of radiocarbon and tritium, and values of Mg/Ca and $\delta^{13}C$ vary spatially and temporally. Hydrochemical data acquired from thousands of water wells over 50 years, and recent hydrochemical and isotope data, suggest that Edwards groundwater chemistry is affected by recharge-zone geomorphology and by climate change at multiple time scales.

Recharge events are marked by increases in concentrations of Ca^{2+}, NO_3^-, activities of radiocarbon and tritium, decreases in Mg^{2+} concentration and Mg/Ca values, and decreases in $\delta^{13}C$. Distributions of data in Ca-Mg/Ca space and in radiocarbon-Mg/Ca space compared with end-member conservative mixing models indicate that Edwards groundwater quality chiefly reflects mixing of low Mg/Ca fresh recharge with higher Mg/Ca resident groundwater. Recharge is most efficient in losing-stream tributary complexes developed on karst-modified Fredericksburg and Lower Washita group strata, and least efficient on poorly karstified drainage divides that are mantled by low-permeability soils derived from clay-rich Upper Washita strata.

Radiocarbon dating of Edwards groundwater is complicated by two competing factors: 1) dissolution of carbonate in the aquifer lowers pmC values, thus producing apparent ages that exceed groundwater mass-ages; and 2) mixing of fresh recharge with older resident groundwater whereby the younger fractions dominate the radiocarbon signal, may mask the presence of older fractions, and produce misleadingly young apparent radiocarbon ages.

Relationships between Mg/Ca and recharge and conservative mixing models enable calculation of the fraction of modern water (lowest Mg/Ca) in Edwards groundwater and estimation of relative recharge rates at well-spacing scales. Mg/Ca-based estimates of the modern-water fractions may enable significant corrections of radiocarbon-based, apparent groundwater ages.

INTRODUCTION

Important issues in aquifer characterization are identification and evaluation of recharge areas in terms of recharge efficiency. This report presents and tests the hypothesis that relative efficiencies of Plateau aquifer recharge areas can be evaluated in short-distance geographical detail on the basis of hydrochemical constituents analyzed at individual wells. In large-scale regional studies where modeling groundwater availability is the main objective, a fairly broad-scale approach is sometimes undertaken where thousands of square miles may be characterized by a single scaling factor for recharge efficiency that is used in conjunction with mean annual rainfall values (e.g., Anaya and Jones, 2008). While this approach is useful as a starting point, practical management of

locally allowable abstraction rates and evaluation of groundwater quality variability (geographical and temporal) require an approach that needs more precise delineation of preferred recharge zones and estimation of local recharge volumes. In this investigation the relationships between hydrochemical and isotopic constituents are used to delineate recharge zones in the Edwards aquifer interval of the Plateau system on the basis of Mg/Ca and its relationship to relative (not absolute) groundwater age. Further, these relationships are inferred to reflect climate changes defined by rainfall abundance.

Findings in this report are consistent with previous investigations of Plateau groundwater quality where hydrochemically conservative mixing of water from disparate origins was concluded to be a major process in the evolution of Plateau system groundwater.

Hydrogeological Setting of the Plateau Aquifer System

The Plateau aquifer system consists of relatively flat-lying, generally southeast-dipping Lower Cretaceous siliciclastic and carbonate strata in the Edwards Plateau of west-central and western Texas (Figs. 2.1, 2.2). The 23,400 sq. mi. (60,606 sq. km.) Plateau ranges from approximately 1,000 ft to 3,400 ft (305 m to 1,035 m) in elevation above mean sea level and encompasses all or part of 21 counties. It is bounded along its southwestern margin by the Rio Grande River valley, along its northwestern margin by the Pecos River valley, along its eastern margin by the Colorado River valley, and along its southern margin by several valley systems whose rivers originate within reentrants along the Plateau margin. Along its northwest margin the Plateau merges with the

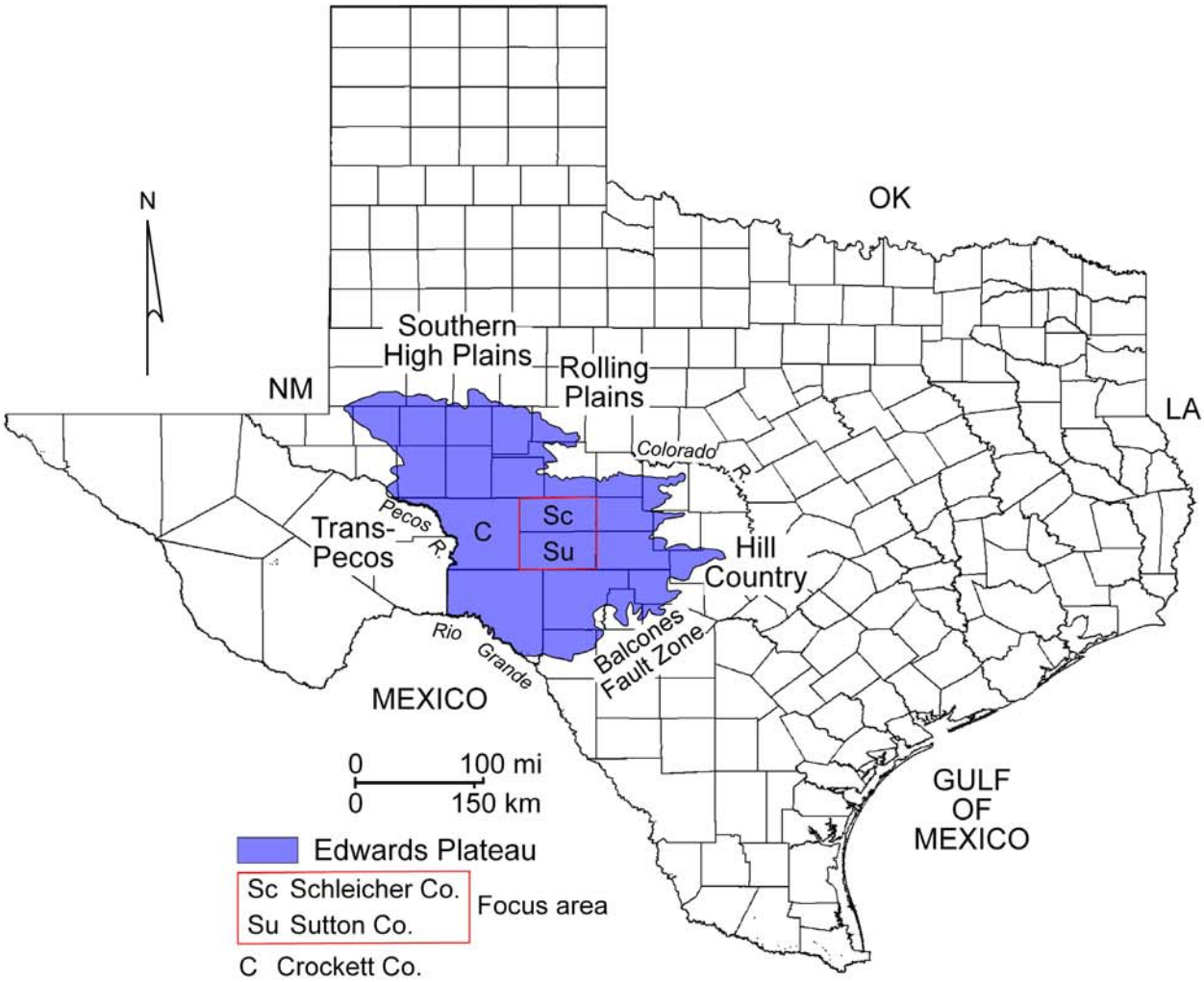

Figure 2.1. Location of Edwards Plateau in West-central and western Texas, surrounding physiographic provinces, major rivers, and county boundaries. Primary focus area of report is also shown.

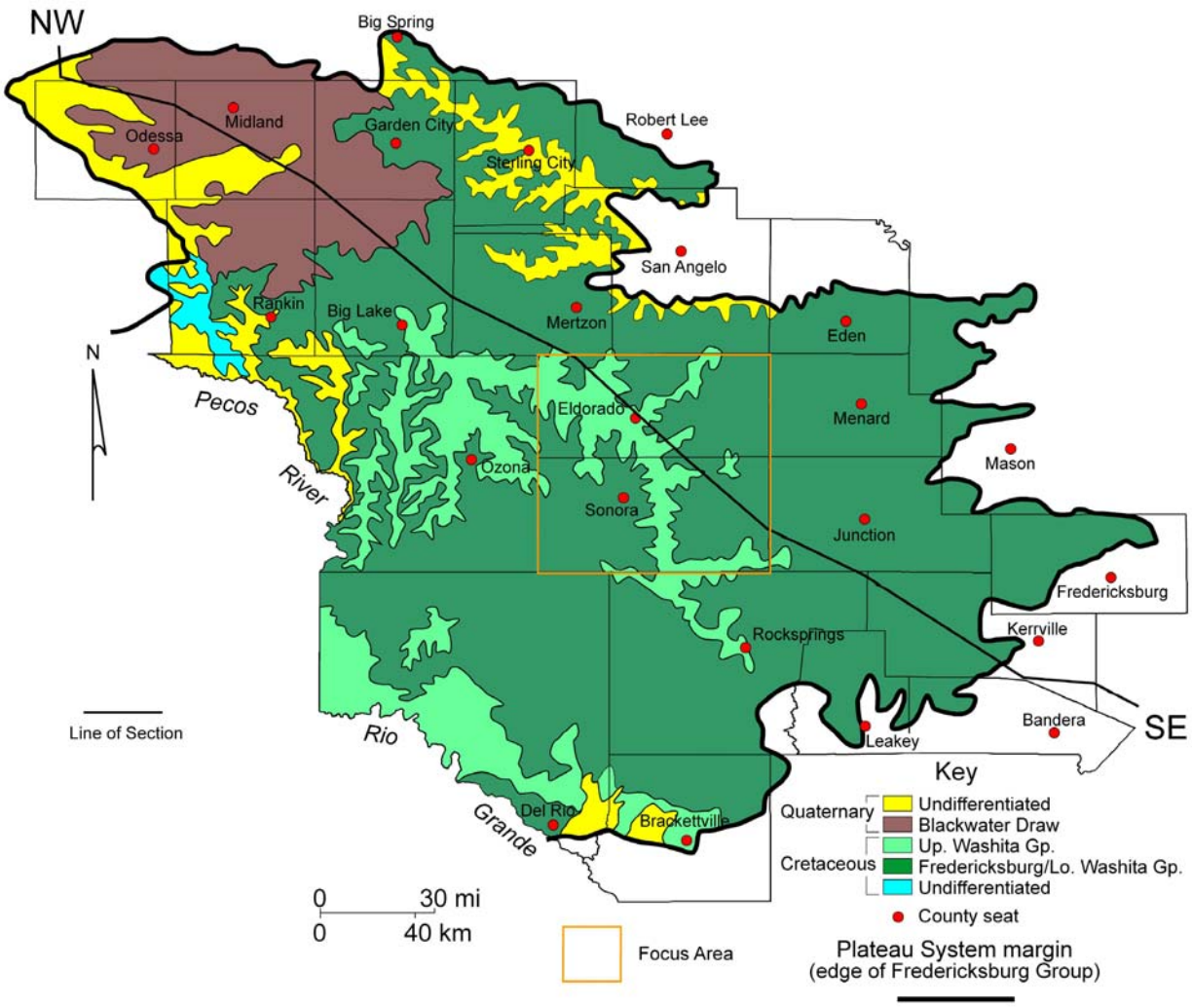

Figure 2.2. Generalized geological map of the Edwards Plateau. Plateau aquifer system is defined by by continuous extent of Fredericksburg Group strata. Also shown are county boundaries, county seats, locations of schematic structural cross section NW-SE (fig. 2.3) and 2-county focus area. Upper Washita strata form the topographically highest areas and drainage divides in the focus area. Modified from BEG, 1992.

Southern High Plains. Topography is flat to rolling along divides, but locally exhibits steep cliffs, mesas, and buttes near streams. Most streams upon the Plateau are intermittent and stream beds probably compose the primary precipitation recharge entrants for the Plateau system, a hypothesis that will be supported below. Widely dispersed small springs occur in the drainage network on the Plateau, but the largest occur at bedding planes along Plateau margins.

Plateau climate, from east to west, ranges from semi-arid to sub-humid. Mean annual rainfall ranges from 14 in to 30 in (355.6 mm to 762 mm) (Larkin and Bomar, 1983). A map depicting mean annual rainfall for the area can be found in Nance (this volume). Timing and distribution of rainfall usually depends on collisions of east- to southeast-moving air masses containing Pacific-derived moisture with northwest-moving air masses containing moisture from the Gulf of Mexico. On average, rainfall intensity peaks in September. However, monthly rainfall measuring close to 6 in (152.4 mm) or more has been recorded for most months between April and October. Over periods of 4 to 10 years mean annual rainfall in the region can range from 8 to 41 in (203 to 1,041 mm), based on San Angelo, TX rainfall records. In a number of cycles with wide rainfall ranges intervening periods between years with lowest and highest rain volumes, respectively, show annual rain volumes that suggest incremental transition between the rainiest and driest years. However, in some cases the transition between a relatively dry year (e.g., 15 in.) and a wet year (e.g., 41 in) can be abrupt. Regionally, average low temperatures range from 10^{o}C to 13^{o}C and average high temperatures range from 25^{o}C to 28^{o}C, averaging 17^{o}C to 21^{o}C annually.

The extent of the Plateau system is defined by the limits of a continuous surface on Fredericksburg/Washita Group rocks (Fig. 2.2). Fredericksburg/Washita Group strata constitute the Edwards aquifer. Except in the northern most 10% or less of the Plateau area direct recharge by rainfall to all the aquifer intervals in the Plateau system is translated through the carbonate strata of the Fredericksburg/Washita Group. The Plateau system comprises Lower Cretaceous strata of the Trinity, Fredericksburg, and Washita Groups (Fig. 2.3). The primary Trinity strata in the study area include the sandstone-dominated Antlers and Hensell Formations, and the carbonate-dominated Glen Rose Formation. Although each of these units is considered an aquifer in groundwater data bases (TWDB, 2008), they are often referred to collectively as the Trinity aquifer. Data from sparse well tests (TWDB, 1969) and county-specific reports (White, 1968), and regional groundwater surveys (Walker, 1979) suggest that the Trinity aquifer is semi-confined to confined by low-permeability intervals at the base of the overlying Edwards aquifer.

Fredericksburg/Washita strata include the Ft. Terrett, Segovia, Ft. Lancaster, Buda, Del Rio , Boquillos, Devils River, West Nueces, McKnight, and Salmon Peak Formations. These are often referred to collectively as the Edwards aquifer in recognition of their age-equivalence to Edwards Group strata in the Balcones Fault Zone and under the Gulf Coastal Plain (Rose, 1972). The Edwards aquifer is the focus in this study and consists of the Ft. Terrett, Ft. Lancaster, and Segovia Formations. The upper surface of the Ft. Terrett Formation is described as bored which often indicates an underlying unit that is well indurated. This may cause at least local confinement of the Ft. Terrett,

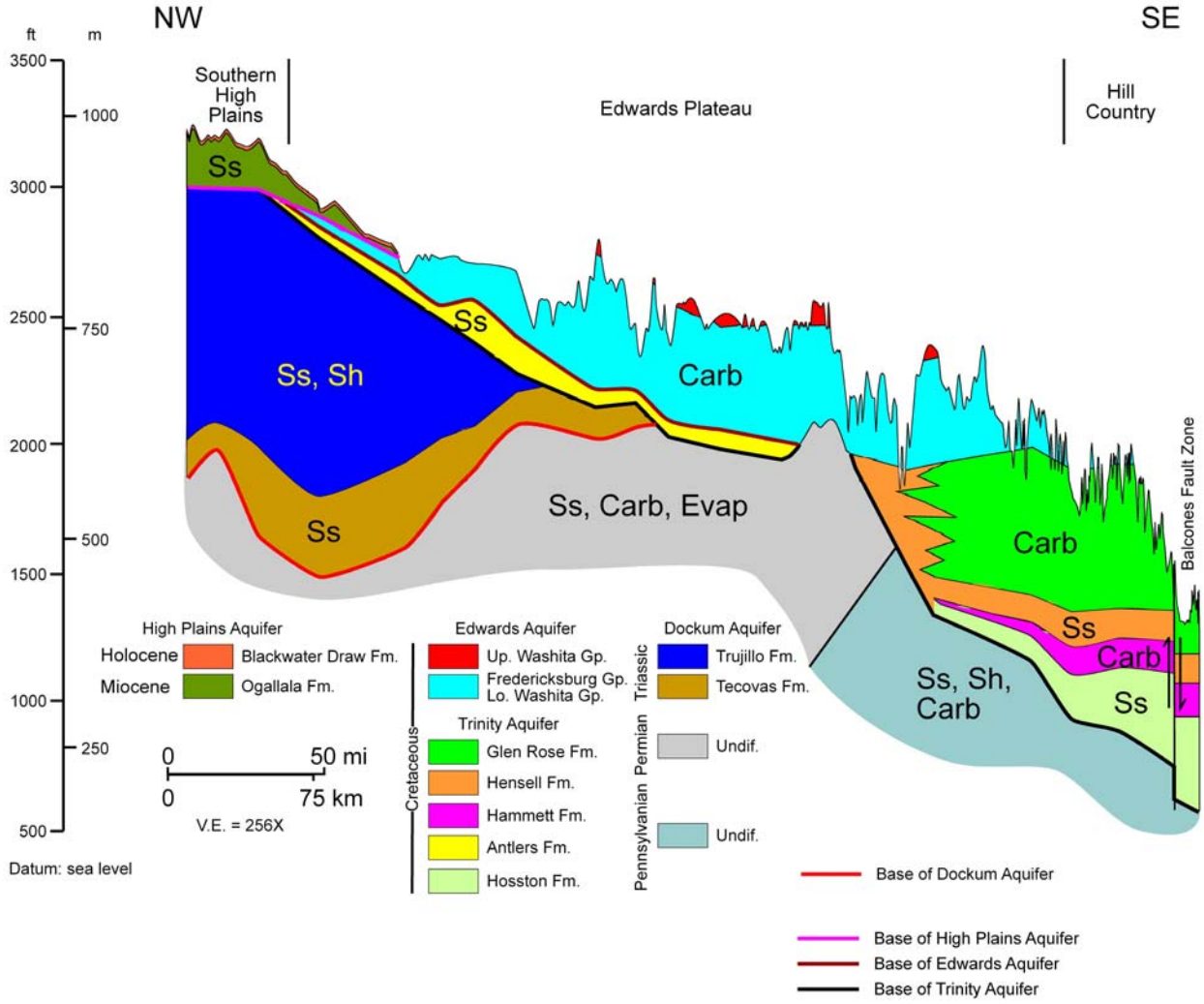

Figure 2.3. Northwest to southeast schematic hydrogeological cross section of the Edwards Plateau showing Cretaceous and contiguous aquifers. Vertical exaggeration is 256X. Modified from Barker and Ardis (1996).

whereas the overlying Ft. Lancaster and Segovia units are probably largely unconfined, based on the widespread distribution of caverns in the Segovia Formation (Atkinson, 2006). The Ft. Lancaster and Segovia Formations interfinger over considerable distances in the area (Smith, 2000). The dominant aquifer is the Ft. Terrett over most of the focus area (Barker and Ardis, 1996). The uppermost units on the Edwards Plateau are the Del Rio and Buda Formations (Upper Washita Group); however, they are restricted to the most elevated parts of the drainage divides and are above the phreatic zone.

The focus of this report in on a 2-county area (Figs. 2.1, 2.2) for which the Edwards aquifer is the sole groundwater productive interval. Edwards groundwater data from other areas, especially Crockett Co. on the western margin of the focus area (Fig. 2.1), also was used in the analysis.

Effective porosity in the Antlers sandstone aquifer is considered to be primary, whereas karst is important in the Edwards aquifer (Walker, 1979). The most permeable part of the Edwards has been suggested to be a dissolution-modified stratiform interval near the base of the aquifer (Barker and Ardis, 1996) due to the preferential dissolution of burrow fillings that left a honeycomb pattern in the remaining matrix (Rose, 1972). Recharge is enhanced by the presence of several stratiform evaporite-dissolution collapse zones that generally are above the saturated zone (Barker and Ardis, 1996; Willis and others, 2001). The role of fractures has not been comprehensively evaluated for Plateau hydrogeology, although the probable influence of fractures on Plateau cave development has been discussed (e.g., Kastning, 1983; Wermund and others, 1978), and the apparent

general control of fractures on Plateau cave morphology is strongly suggested by maps of Plateau caves (e.g., Kastning, 1983; Elliot and Veni, 1994).

The Plateau system is underlain by Triassic and Upper Paleozoic units (Fig. 2.3) (Barker and Ardis, 1992) and overlain by Cenozoic to recent units (e.g., Nativ, 1988) whose ancestral and present hydraulic relationships with the Plateau system are important to the understanding of Plateau system hydrochemistry. A comprehensive summary of the hydrogeological framework of the Plateau aquifer system can be found in Barker and Ardis (1996).

Previous Investigations

Previous workers have developed regional-scale information on the Edwards-Trinity (Plateau) aquifer system (Fig. 2.1) focusing on the hydrogeological setting (Walker, 1979; Barker and others, 1992, 1996; Barker and others, 1994), modern climate (Bradley and Malstaff, 2004), paleo-climate (Toomey and others, 1993), soil formation (Cooke and others, 2003; Cooke and others, 2007), distribution of hydraulic heads (Kunianski, 1990; Bush and others, 1993), flow models (Kuniansky and Holligan, 1994), and groundwater availability models (Anaya and Jones, 2004).

Reports of more local features that provide important insights into Plateau system hydrodynamics include work on karst and cave systems in the Plateau (e.g., Freeman, 1968; Kastning, 1983; Veni, 1994; Willis and others, 2001), Plateau fracture systems (Wermund and others, 1978), and work on the temporal variations of groundwater chemistry based on drip water in Central Texas caves by Musgrove and Banner (2004).

Several local-scale discussions of Edwards hydrogeology include Blank and others (1966) for an area that includes the focus area for this paper. Local recharge evaluations have been all but absent, a notable exception being for Kinney County (Mace and Anaya, 2004), the northern part of which is on the Edwards Plateau.

Prior to the present study comprehensive hydrochemical investigations of regional scope for the Edwards-Trinity (Plateau) aquifer system are those of Walker (1979), Bush and others (1994), and Nance (2004). Walker (1979) provided the first summary of water quality in the Edwards Plateau which focused on distributions of TDS and major anionic species based on analyses of widely spaced wells. Bush and others (1994) summarized the distribution of dissolved solids and hydrochemical facies based on averaging analyses of multiple wells in 36-sq.-mi. areas; and Nance (2004) that focused on patterns of anionic hydrochemical variability based on analyses of individual wells, and presented evidence that ion exchange was a probably a major influence on stratigraphically variable cation distributions in the Plateau system. Hopkins (1995) provided a summary of the distribution of hydrochemical constituents in the region with an emphasis on potential contaminants and nutrients. The most recent study is Nance (this volume) that uses distributions and relationships between stable isotopes, radiogenic isotopes, and conservative anions in Plateau system groundwater to propose that hydrochemical variability in the system is related to cross-formational upward flow into the Plateau system from Paleozoic and Triassic aquifers and mixing with modern recharge. Much of the data and hydrological interpretations presented in this paper are new for the Edwards

Plateau, provide a basis for future study, and should find applications in analyses of other carbonate aquifers.

METHODS

Samples were collected from wells with activated submersible pumps after pH, temperature, and electrical conductivity values stabilized. Field parameters were monitored for stabilization with a Hach Hydrolab Quanta multi-probe. Samples for cations and anions were passed through 0.45μ non-reactive syringe filters into separate containers. Splits for cation analysis were stabilized with nitric acid; splits for NO_3^- were stabilized with sulfuric acid. Splits for anions and isotopes of oxygen, hydrogen, strontium, and carbon were untreated. All samples were placed on ice and maintained at approximately 4^oC until received by the analytical laboratories.

Major and minor ions were analyzed by standard methods at Energy Laboratories (Casper, WY).

Strontium isotope analyses were performed at the University of Texas, Jackson School of Geosciences on a Finnigan-MAT 261 thermal ionization mass spectrometer using auto-dynamic techniques. A volume of water containing at least 250 mg of Sr was pipetted into a Savillex Teflon vial containing 50 μL of 7 N HNO_3 (to convert any HCO_3^- to NO_3^-). The sample was dried, then the Sr was isolated using Eichrom Sr-specific resin. Samples were loaded onto zone-refined Re filaments along with 0.3 M H_3PO_4 and Ta_2O_5. Procedural blanks were consistently less than 15 pg of Sr. Results were normalized for fractionation to $^{86}Sr/^{88}Sr = 0.1194$ using an exponential fractionation law.

mean value of 0.710261 was determined for standard analyses of NIST-SRM 987 (external 2ρ = +/-0.000015 for auto-dynamic runs, n = 50).

Stable-hydrogen- and oxygen-isotope analyses were performed at Southern Methodist University. For $\delta^{18}O$ analysis two to five mL of sample water is equilibrated overnight at 25°C with CO_2 gas of known carbon isotopic composition. The equilibrated CO_2 gas is cryogenically purified, loaded into a sample tube, and is analyzed on a mass spectrometer. At least one in-house laboratory standard is analyzed with each set of unknown samples (no less than one for every 15 samples). Results from the standard runs indicate an analytical precision of $\leq \pm 0.10$ ‰. As a secondary check, the carbon isotopic composition of the CO_2 gas obtained from the procedure is compared to the initial carbon isotopic composition of the CO_2 equilibration gas.

For δD analyses five μL of cryogenically purified sample water is reduced to H_2 gas by passing it over depleted uranium metal at 800°C. The H_2 gas is collected onto activated carbon at liquid nitrogen temperature. Results from the standard runs and from duplicate analyses indicate an analytical precision of approximately ± 1 ‰. All isotopic measurements are made on either a Finnigan MAT 251 or Finnigan MAT 252 mass spectrometer. In-house standards, which are calibrated with international standards, are run with each batch of samples as a check on procedural uniformity. Every fifth sample is repeated as a check on reproducibility.

Tritium activity analyses were performed by using the gas proportional counting method at the Tritium Laboratory at the University of Miami, Rosenstiel School of Marine and Atmospheric Science. 300 mL of the water sample are distilled with

continuous reflux to dryness or near dryness. During the procedure, the still is vented to the ambient air through a drying agent to avoid contamination of the sample by atmospheric water vapor. The volume of the sample is reduced from 275 to 5 mL while preserving a large fraction of the tritium. The normal starting volume is 275 mL of which 75 mL are charged into an electrolytic enrichment cell. To that portion, 2 mL of concentrated sodium hydroxide solution (made from dead water and sodium peroxide or oxide) is added, and the remainder of the sample is transferred to a container on top of the cell. The sample is electrolyzed for 24 hours at 5 amps, current-regulated, which removes 50 mL of water. Once a day the solution in the cell is topped up from the container to the 75 mL mark, and the procedure is continued. When a total of between 20 and 50 mL of the sample remains, power is changed to constant voltage of 3.15 V, and later reduced to 2.75 V, until the process stops at the lower edge of the anode, leaving about 5g of enriched sample. This procedure takes 10 - 14 days, and the remaining amount of water typically contains 80% of the original amount of tritium. The enriched water sample is vacuum distilled from the sodium hydroxide, and the yield is weighed to – 2 mg, and the value is adjusted for hydrogen left in the sodium hydroxide. About 3 mL of the enriched water sample is injected into a vacuum system. The water evaporates, and the vapor is reduced by hot magnesium metal to hydrogen gas which is absorbed on activated charcoal at liquid nitrogen temperature in a stainless steel pressure cylinder. Approximately 4 L atm of hydrogen is obtained this way. The low-level gas proportional counters have an active volume of 1 L and are shielded by 2.5 cm of selected lead, a ring of anti-coincidence Geiger counters, 10 cm of paraffin wax, boric acid and/or borated

polyethylene, and at least 20 cm of iron, plus the walls and ceiling of the building. The counter is first filled with 10 psi (67 kPa) of propane. Thereafter, the sample hydrogen gas, under pressure in its cylinder, is added to the counter for a total pressure of 40 psi (300 kPa). The counter is then sealed off, and the gas amplification is set to specifications by adjusting working voltage using an external radioactive source. After that, counting proceeds until criteria for accuracy or sensitivity have been met. The pulses are sorted into several channels, of which some are used for continuous control of the gas amplification, as shown in the cosmic radiation spectrum, etc. Counting times are 6 to 20 hours. A 1 TU original sample enriched from 275 to 6 mL typically shows 0.6 cpm in the tritium channel above a background of 0.40 cpm, known to – 0.02 cpm. At least once weekly each counter counts dead hydrogen gas (from petroleum). In addition, water from the deep Floridan Aquifer (more than 10,000 years old water) is reduced to occasionally check on the tank hydrogen gas. This procedure sets the background count of the counting equipment. Each batch of sodium hydroxide solution is also tested for blank value. A further check on process blanks is that at least once a week a sample of dead water (from the Floridan Aquifer) goes through all the same procedures, including enrichment, as the unknown samples. In order to check on the efficiency of the enrichment procedure, at least once a week a sample of known activity is processed through the entire system of enrichment, reduction, and counting. The efficiency of each counter is determined by counting hydrogen gas made by reduction of standard water in our regular preparation system. This standard water is prepared from NIST (formerly United States National Bureau of Standards) SRM #4926 by dilution by weighing. The

dependence of background, efficiency, etc., on pressure, gas composition, gas amplification, etc., is known, and the appropriate corrections are applied via the software of the computing system.

Radiocarbon (^{14}C) analyses were performed at Beta Analytic Inc. in Miami, Florida by using the AMS method. Groundwater apparent ages were calculated from percent modern carbon (pmC) by Beta Analytic assuming initial ^{14}C activity to be 100% of modern activity with a half-life of 5,568 years. Results are derived from reduction of sample carbon to graphite (100 %C), along with standards and backgrounds. The graphite is then sent for ^{14}C measurement in an accelerator-mass-spectrometer located at one of six collaborating research facilities, who return the results to Beta for verification, isotopic fractionation correction, calendar calibration, and reporting. The standard for modern carbon is Oxalic Acid II obtained from National Institute of Standards and Technology. $\delta^{13}C$ values also were determined during this procedure.

Databases were manipulated and statistics reduced in Microsoft Excel. Mapping was initially performed in ESRI ArcGIS and finalized in Macromedia Freehand.

Hydrochemical and isotopic data used for this project were acquired from analyses of samples obtained from water wells completed in the carbonate (limestone and dolostone) Edwards aquifer on the Edwards Plateau. Wells completed in this interval are typically open-hole completions (Walker, 1979). Data on exact completion depths are not available for every well and the condition of individual boreholes is very poorly known, including the distribution of natural fractures. Driller's reports suggest that solution cavities are common and widespread, although their connectivity is unknown. For these

reasons stratigraphic control for sample origin is limited to aquifer interval, the identity of which has been determined by the Texas Water Development Board.

DATA

Data for this study include over 1,650 charge-balanced (+/- 5%) hydrochemical analyses performed during or after 1960 representing approximately 1,275 Edwards aquifer wells completed in three counties on the Edwards Plateau (Fig. 2.4). These data are maintained by the Texas Water Development Board (TWDB, 2008). Additional data were developed during a sampling campaign undertaken in 2006 and 2007 for which groundwater samples from 28 wells completed in the Edwards aquifer. Analyses used for this investigation are found in A2.1 and A2.2.

RESULTS

Edwards groundwater in the Plateau system exhibits a wide range of variation in constituent concentrations, constituent ratios, and apparent radiometric ages. The values reported in this section are shown in the following section probably to reflect variable residence times, spatially-variable dominance of waters with different flow histories, and mixing of waters with different histories. This report uses brackets to indicate ionic concentration (e.g., $[Ca^{2+}]$), whereas brackets and ionic charge are eliminated for ratios (e.g., Mg/Ca).

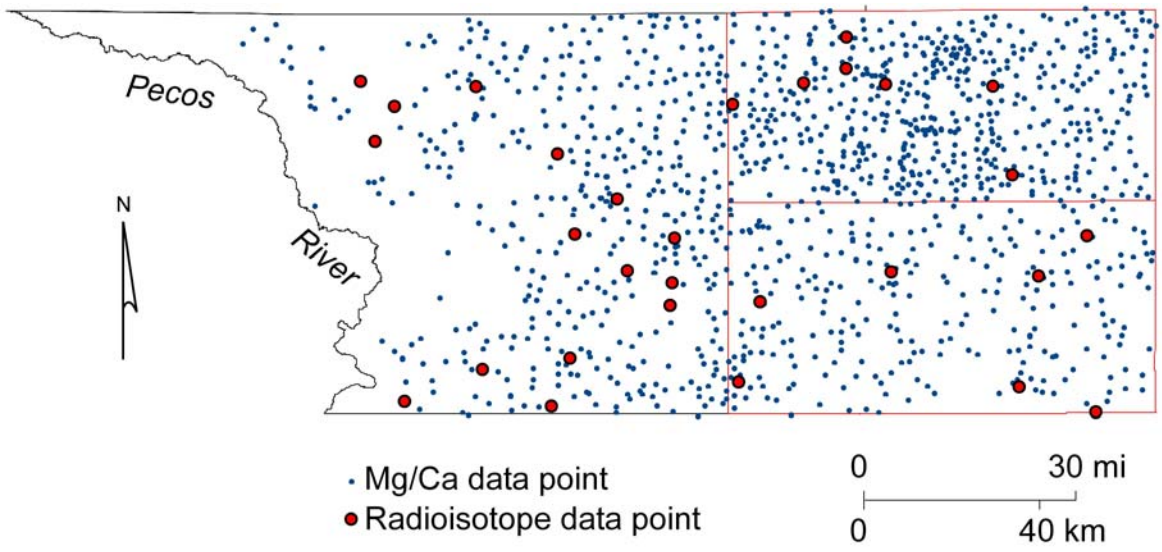

Figure 2.4. Location of Edwards aquifer wells from which data was used to calculate Mg/Ca values. Also shown are locations where radioisotope data were also obtained.Red county boundaries outline focus area for which percent modern water values were calculated from Mg/Ca-radiocarbon relationships. Data from TWDB (2007).

Constituents of Plateau System Groundwaters

Major Ions

Based on the most recent analyses for each of the wells in the focus area (Fig. 2.4) with available Edwards hydrochemical data (TWDB, 2008) [TDS] ranges approximately from 180 mg/L to greater than 8,200 mg/L (median 281 mg/L); [Ca^{2+}] ranges from 18 to 680 mg/L (median 61 mg/L); [Mg^{2+}] ranges from 1.3 to 263 mg/L (median 22 mg/L), [Na^{-}] ranges from 2 to 2,670 mg/L (median 13 mg/L); [HCO_3^{-}] ranges from 104 to 503 mg/L (median 264 mg/L); [SO_4^{2-}] ranges from 3 to 830 mg/L (median 14 mg/L); [Cl^{-}] ranges from 2 to 4,900 mg/L (median 20 mg/L); and [NO_3^{-}] ranges from 0 to 1,130 mg/L (median 6.4 mg/L). Mg/Ca values (molar) range from 0.02 to 5.22 (median 0.59). Na/Cl values range from 0.33 to 4.6 (median 1.03).

Isotopes

In the focus area $^{87}Sr/^{86}Sr$ values range from 0.70770 to 0.70829 (median 0.70795) (Fig. 2.5), $\delta^{13}C$ ranges from -11.1 ‰ to -6.3 ‰ (median -9.0 ‰), ^{14}C ranges 0.125 0.611 pmC (median 0.393 pmC) (Fig. 2.6), and tritium ranges 0 – 1.56 T.U (median 0.5 T.U.) (A2.1).

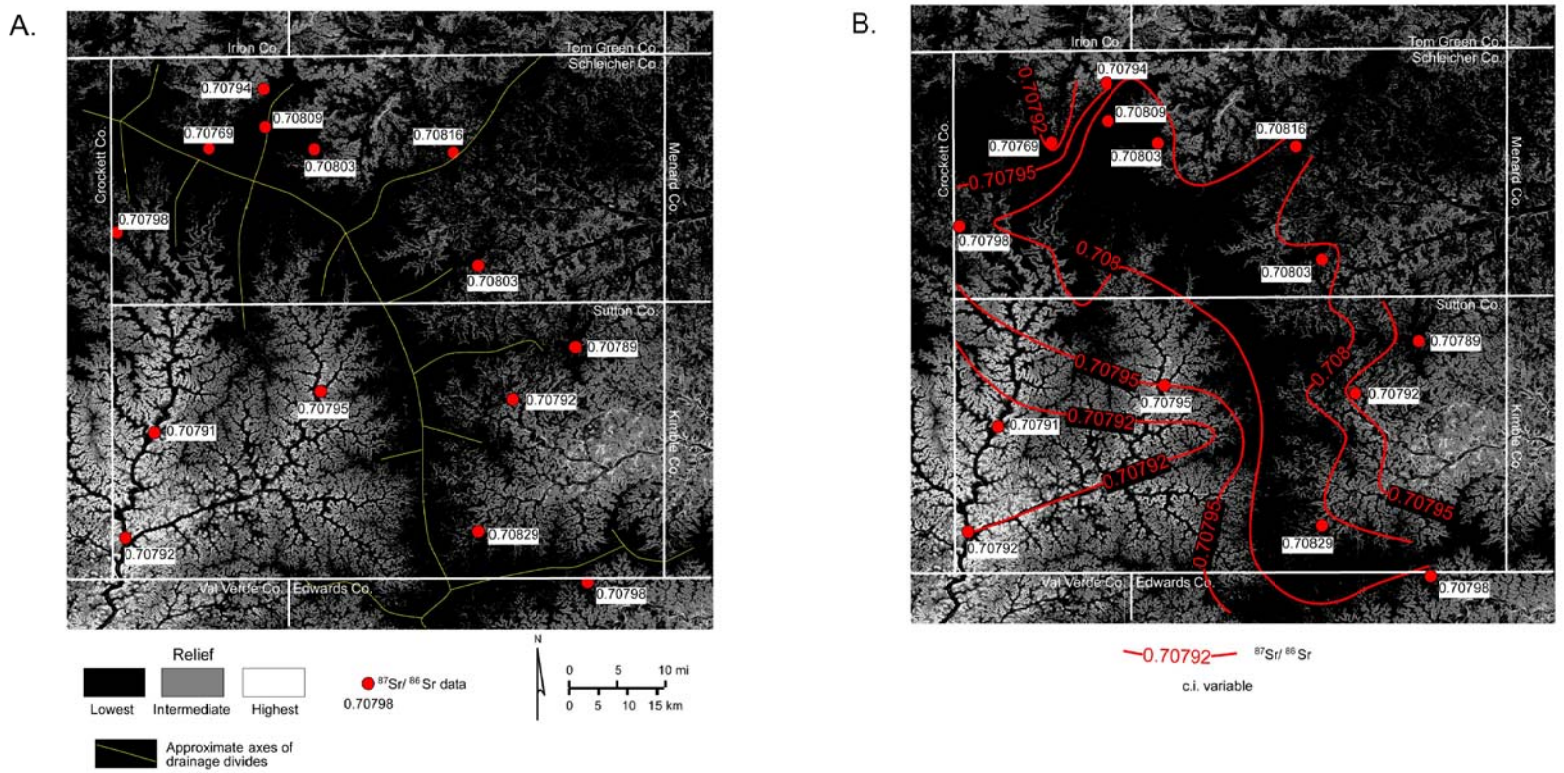

Figure 2.5. Topographic relief maps showing distribution of strontium isotope values in the focus area. Also shown are A) approximate positions of topographic divides; and B) interpretative contours based on Sr-isotope values and concept that higher values preferentially occur along the regional topographic divide.

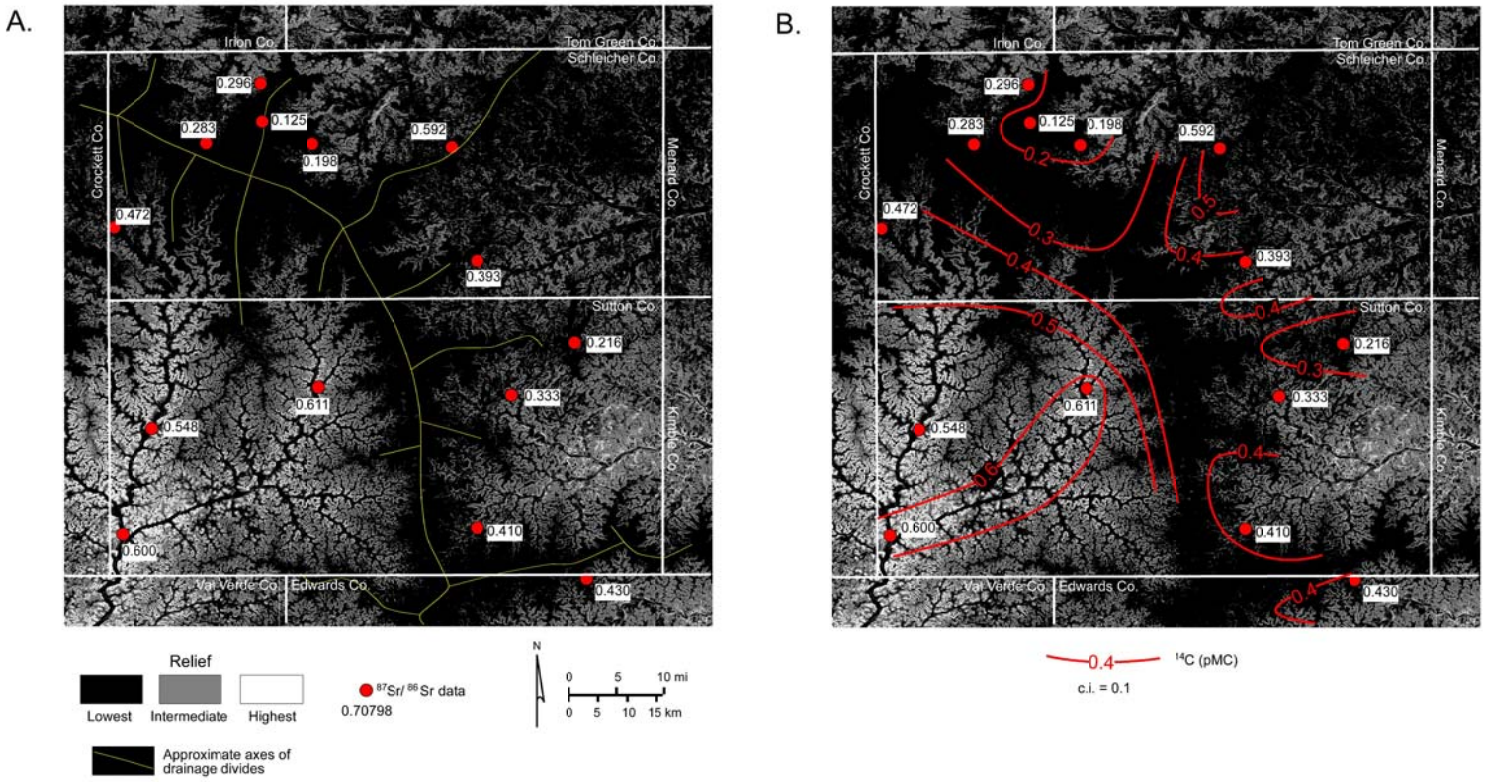

Figure 2.6. Topographic relief maps showing distribution of percent modern carbon (pmC) values in the focus area: Also shown are A) approximate positions of topographic divides; and B) interpretative contours based on concept that higher values reflect higher rates of recharge within losing-stream networks.

DISCUSSION

Origins of Edwards Aquifer Groundwater Constituents and Distribution in Focus Area

Major Ions

Edwards groundwater is Ca-HCO_3 type in the study area with rare local exceptions. Charge balances between [Ca^{2+}], [HCO_3^-], and [SO_4^{2-}] are generally consistent with dissolution of calcite, dolomite, and anhydrite/gypsum. Balances between [Na^-] and [Cl^-] are consistent with dissolution of NaCl. NO_3^- is not reported anywhere in Edwards Plateau strata of any age and its origin is from degradation of organic matter at or near the land surface. [Ca^{2+}], [Mg^{2+}], and [NO_3^-] show geographic and temporal variability. The general magnitude in [Ca^{2+}] and [Mg^{2+}] generally parallels that of the dissolved solids content, whereas the value of Mg/Ca does not.

[NO_3^-] regional variability most closely reflects proximity to agricultural areas in the northwest part of the Plateau region. In the focus area of this report (Figs. 2.1, 2.2) [NO_3^-] range from 0.04 to 68 mg/L (median 7.0 mg/L). The more elevated [NO_3^-] values in the focus area tend to occur in water from wells completed away from the prominent regional drainage divide that occurs on the outcropping Upper Washita rocks (Fig. 2.2).

These are areas where vegetation may be more abundant generally because runoff is focused into drainages and, as is shown, where most surface water probably enters the aquifer. Temporal variability in groundwater [NO_3^-] is seen in wells for which there is a history of sampling events. Temporal variability of [NO_3^-] and other constituents, and implications for recharge evaluation are discussed in a later section.

Strontium Isotopes

$^{87}Sr/^{86}Sr$ values in Edwards groundwater greater than 0.7076 (average Cretaceous normal marine value) probably reflect a significant Rb-bearing siliciclastic component in host rocks in the system. Some Edwards carbonates contain minor amounts of clay and may contribute $^{87}Sr/^{86}Sr$ to groundwater.

Carbon and Radiogenic Isotopes

Stable carbon isotopes in Edwards groundwater originate mainly from dissolution of carbonate minerals, water-soluble organic compounds, and organic soil-gas (CO_2). ^{12}C is the dominant form of carbon in CO_2 and in sedimentary carbonate minerals. ^{13}C is a rarer form of carbon (approximately 1.1 % of all carbon), but is measurably more abundant in marine carbonate than in pedogenic CO_2. ^{13}C averages about 23‰ less abundant in pedogenic $^{13}C/^{12}C$ than in the $^{13}C/^{12}C$ of marine limestone. Pedogenic CO_2 originates mainly from decay in the soil of organic matter. Plant material tends to exhibit higher $^{13}C/^{12}C$ than the atmosphere because of thermodynamically selective respiratory processes. Average $\delta^{13}C$ in soils is approximately -23‰ PDB (Wickman, 1952; Craig, 1953) whereas $\delta^{13}C$ in marine limestone is about 0‰ PDB. When initially dissolved in water, CO_2 is sequestered in the form of H_2CO_3. However, HCO_3^- is the primary dissolved carbonate species in water residing in the soluble carbonate-rich soils developed on the Edwards Plateau carbonate bedrock. The integration of organic and inorganic carbon into HCO_3^- during the soil-mineral dissolution process is the first of a series of processes that complicate radiocarbon age-dating of groundwater because it is at

this stage that the atmospheric $^{14}C/^{12}C$ signature in modern rainwater-sourced recharge is compromised by the addition of dissolved mineral-based non-radiogenic carbon.

Tritium (^{3}H, half-life = 12.3 yr) and radiocarbon (half-life = 5,568 yr) both form in the upper atmosphere by cosmic ray bombardment of ^{14}N and decay by β^- emission. Tritium is incorporated into water molecules and enters the aquifer system with rainfall. Radiocarbon is incorporated into atmospheric CO_2 molecules which are then concentrated in plant material through photosynthesis. Although some atmospheric CO_2 is dissolved in rainfall, recharge water obtains most of its dissolved CO_2 load from soil gas generated by organic decay because the average pCO_2 in soil is one to three orders of magnitude greater than in the atmosphere (Russell, 1952, cited in Ingerson and Pearson, 1964).

Tritium and radiocarbon activities are positively correlated (Fig. 2.7A). Tritium-radiocarbon correlations, which improve when data is plotted on a county-scale basis compared to the regional scale, lend confidence that radiocarbon can be used to order samples according to relative apparent age.

Radiocarbon, tritium, and Mg/Ca are positively correlated with $\delta^{13}C$ (Fig. 2.8). Values of $\delta^{13}C$ are increasingly negative overall for increasing activities of radiocarbon and tritium, thus suggesting that apparently younger waters have a stronger soil-gas signal than older waters. Similarly, the $\delta^{13}C$ correlation with Mg/Ca values, suggests that waters with lower Mg/Ca values have a stronger soil-gas signal than do waters with more elevated Mg/Ca values. These data suggest that waters with lower Mg/Ca and $\delta^{13}C$ values

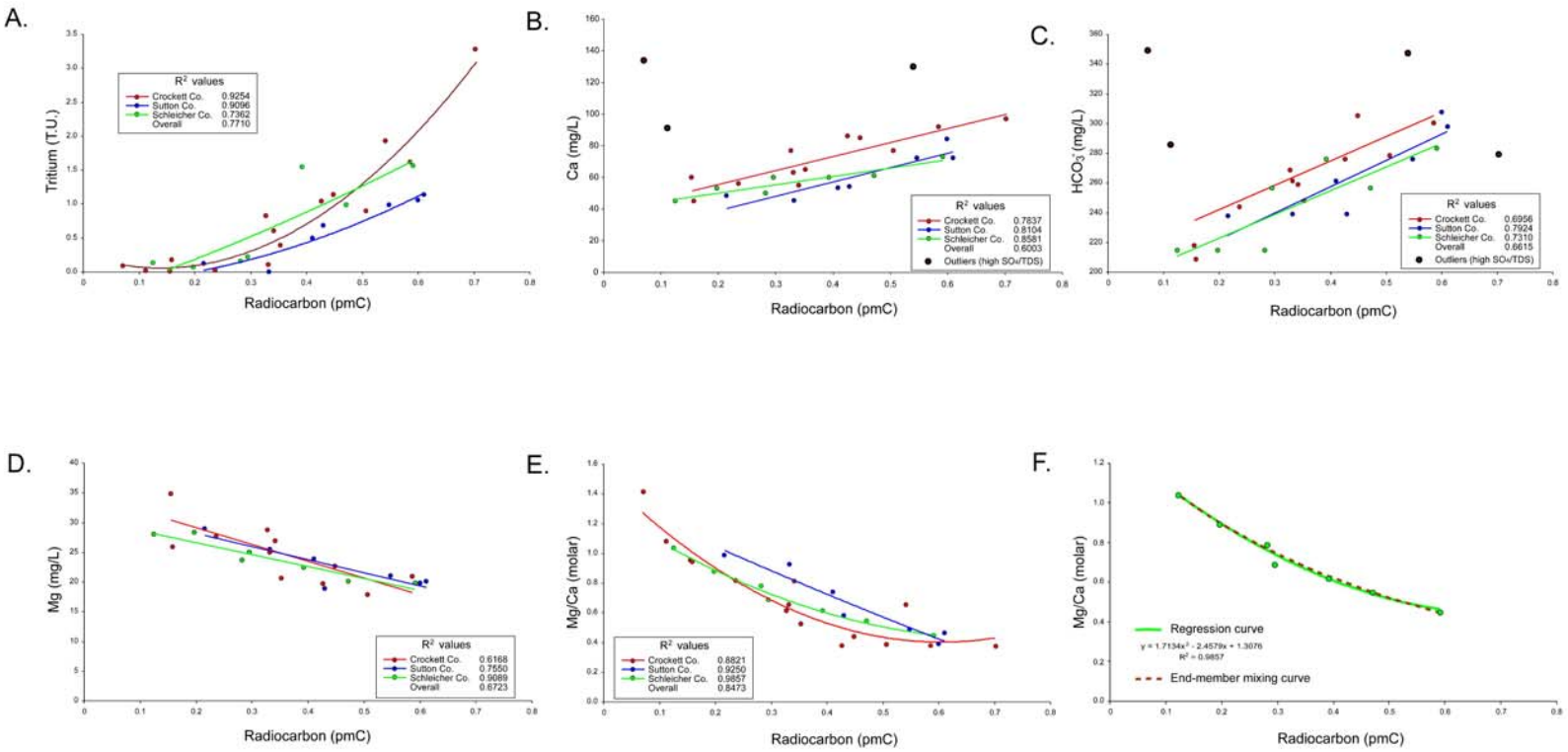

Figure 2.7. Graphs showing relationships between radiocarbon activity, tritium activity, and major ions in Edwards groundwater in the focus area: A) tritium vs radiocarbon; B) Ca^{2+} vs radiocarbon; C) HCO_3^- vs radiocarbon; D) Mg^{2+} vs radiocarbon; E) Mg/Ca vs radiocarbon; and F) Mg/Ca vs radiocarbon for samples collected from Schleicher County. Also shown are regression curves for county-specific data and R^2 values. Outliers from Crockett Co. in B) and C) arenot included in calculation of R^2 to emphasize trends shown by the majority of the data.

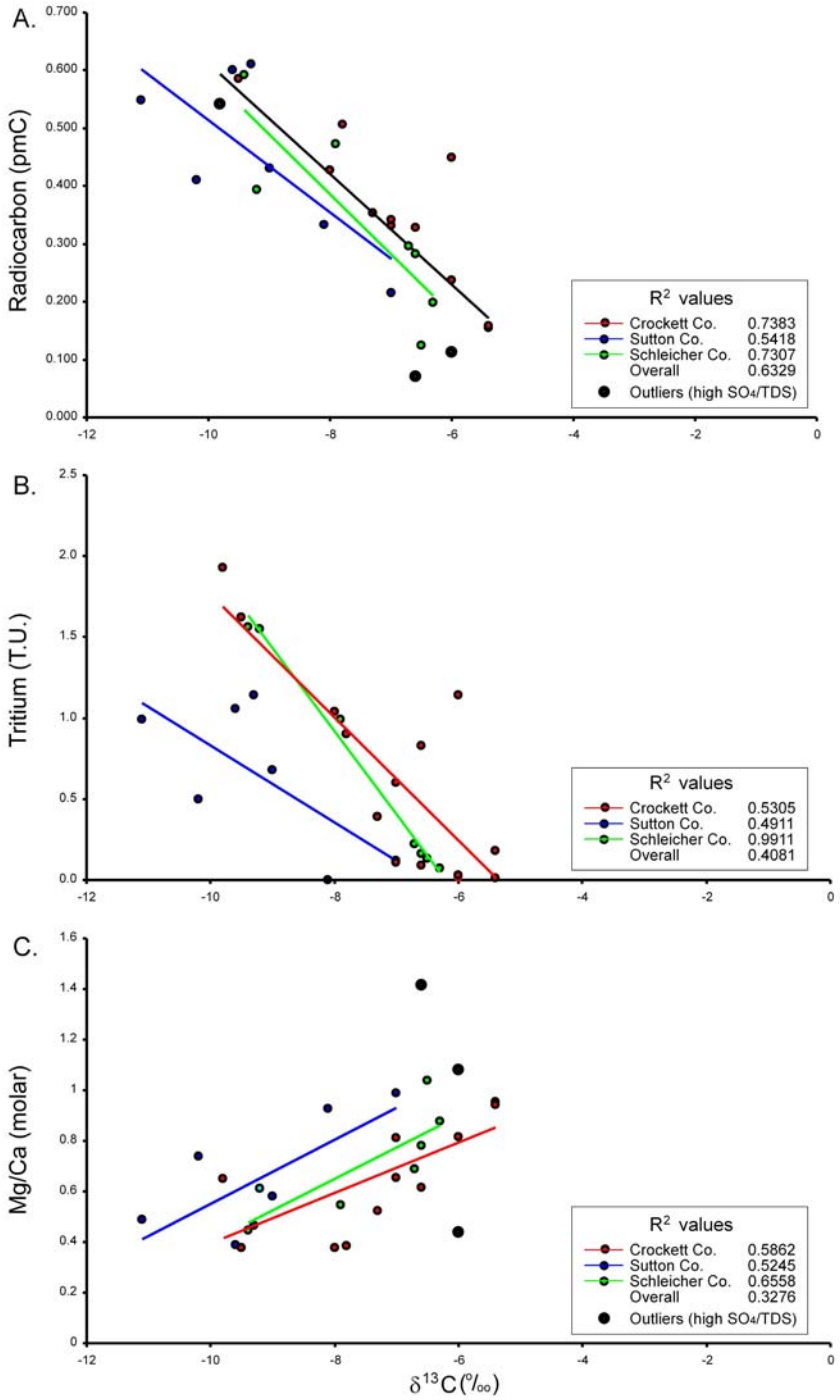

Figure 2.8. Graphs showing relationships between $\delta^{13}C$ and A) radiocarbon, B) tritium and C) Mg/Ca values for samples collected from the Edwards aquifer in the study area. Note that $\delta^{13}C$ more closely approaches soil-like depleted values as radiocarbon increases and as Mg/Ca decreases. County-specific data are color-coded. These data, in conjunction with relationships between tritium, radiocarbon, and Mg/Ca (fig. 2.7) support the conclusion that recharge timing largely controls radiocarbon and Mg/Ca values. Outliers from Crockett Co. in B) and C) are not included in calculation of R^2 to emphasize trends shown by the majority of the data.

contain a higher fraction of recent recharge than do older waters. These findings are important in developing the concept that Mg/Ca can be applied as a proxy for groundwater relative age and as an indicator of relative recharge efficiency.

Hydrochemical and Isotopic Variability in the Edwards Aquifer

Edwards water quality generally is a fresh (median [TDS] = 281 mg/L) Ca-HCO_3 hydrochemical facies with rare isolated exceptions originating from probable human activity. However, variability in the relative proportions of major ions is significant, provides clues to the aquifer flow dynamics, and suggests practical applications for groundwater management which are increasingly important on the semi-arid parts of the Plateau where life and industry rely on groundwater resources. Of particular interest are controls on geographical and temporal variability of Mg/Ca values which range over 2 orders of magnitude.

Previous workers have used Mg/Ca values in groundwater to interpret the composition of aquifer matrices or have interpreted Mg/Ca as indicative of recharge rates. For example, Mg/Ca values approaching or exceeding 1 suggests that the aquifer is composed of dolostone because the groundwater Mg/Ca is presumed to be approaching equilibration with dolomitic aquifer matrix or recording dolomite dissolution (e.g., Langmuir, 1971; Hanshaw and others, 1971). Musgrove and Banner (2004) observed temporal variations for Mg/Ca values in cave dripwaters in Central Texas carbonates. They attributed higher Mg/Ca values to longer groundwater residence times and more extensive Mg-bearing carbonate dissolution.

Findings in this study indicate that phreatic groundwater Mg/Ca can vary significantly through time, Mg/Ca values are not necessarily indicative of aquifer dominant lithology, and that mixing of waters with diverse origins may control Mg/Ca in addition to other constituent values. Mixing of groundwaters in the Edwards aquifer with water from the underlying Antlers, perhaps even from the evaporite-bearing Permian section, was proposed to explain geographically variable SO_4/TDS values in the Edwards (Nance, this volume).

Strontium Isotopes

In the focus area higher $^{87}Sr/^{86}Sr$ values (>0.708) occur in the vicinity of the regional topographic divide (Fig. 2.5). Lower values tend to be more common in the drainages down slope of the divide. The contour patterns shown in Figure 2.5B reflect this conceptual model, although more abundant and more widely distributed data are required to confirm the conceptual model.

Values of SO_4/TDS and $^{87}Sr/^{86}Sr$ are well correlated if the data are considered in geographically distinct groups: 1) the drainages in the southern part of the area; 2) the drainages in the northern part of the area; and 3) the locations closest to the regional topographic divide (Fig. 2.9A). Within each of these provinces r^2 values for linear regressions exceed 0.98, whereas R^2 for the undifferentiated data is 0.338.
Higher $^{87}Sr/^{86}Sr$ values may reflect a significant component of recharge that has been affected by siliciclastic detritus in the soil zone. This second option was suggested by Musgrove and Banner (2004) to explain increases in $^{87}Sr/^{86}Sr$ in cave drip waters during recharge events as recording increases of dissolved constituents from siliciclastic-

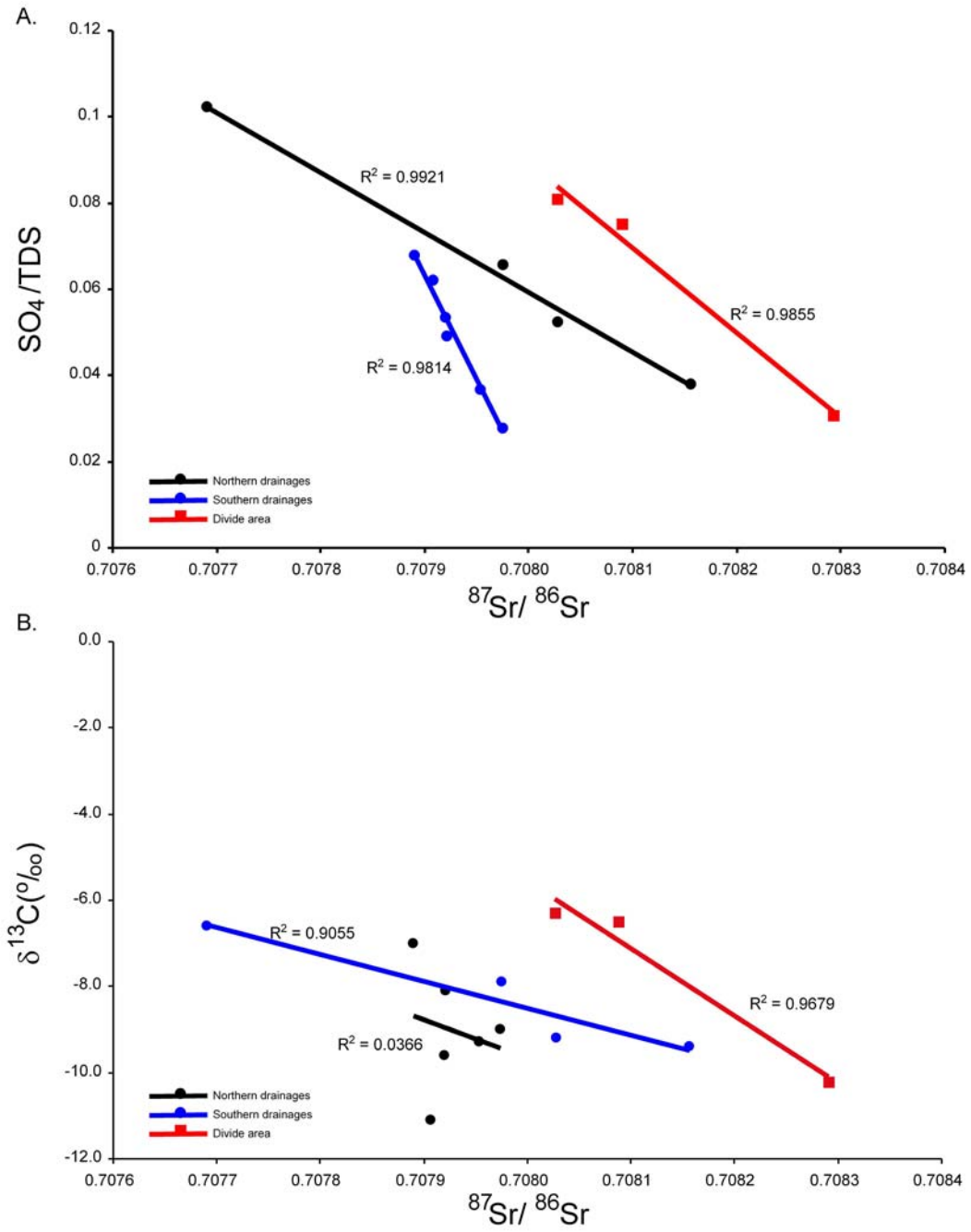

Figure 2.9. Graphs showing relationships between Sr-isotopes and A) SO_4/TDS; and B) $\delta^{13}C$. Data are color-coded according to their location within three topographic provinces:1) stream networks in the northern part of the area, 2) stream networks in the southern part of the area, and 3) the regional divide area. Increases in $^{87}Sr/^{86}Sr$ with corresponding decreases in SO_4/ TDS and $\delta^{13}C$ values suggest that more radiogenic- and lower-SO_4/TDS groundwaters have a greater affinity to soil-water than do waters with higher SO_4/TDS and lower $^{87}Sr/^{86}Sr$ characteristics.

bearing soils. Notably, the more eastern parts of the Edwards aquifer focus area get a couple of more inches of mean annual rain (Larkin and Bomar, 1983). Higher $^{87}Sr/^{86}Sr$ in this area may reflect more extensive entrainment by recharge of ^{87}Sr from the soil zone. $\delta^{13}C$ data in two of the provinces show a pattern of increased negativity with increased $^{87}Sr/^{86}Sr$ values where R^2 values for linear regressions exceed 0.9 (Fig. 2.9B). Such correlations are understandable if leaching of soil is a control on elevating $^{87}Sr/^{86}Sr$ values. Other data from the area also indicate that decreasing $\delta^{13}C$ is one of several recharge signals and is discussed further in another section.

It is notable that Figure 2.9A shows that the more elevated SO_4/TDS values in each of the provinces correspond to lower $^{87}Sr/^{86}Sr$ values. This correspondence suggests that waters with lower SO_4/TDS, presumably indicative of recharge, are the more radiogenic. This finding is consistent with the proposal that soil siliciclastics also are a source for radiogenic strontium in focus area groundwater than are siliciclastics in the Antlers Formation or Permian section. This hypothesis is supported by the relationship between Sr-isotopes and $\delta^{13}C$ values for many of the same samples (Fig. 2.9B) that suggests that some of the more radiogenic waters have $\delta^{13}C$ values suggestive of soil gas. The overall higher $^{87}Sr/^{86}Sr$ values in the samples collected nearest the divide may reflect the lower permeability of the soils whereby residence time of recharge in soil is greater than it is in the drainages which are characterized by losing streams with thinner soils where recharge rates are higher. The suggestion that higher recharge rates occur away from topographic divides will be discussed more extensively later.

Carbon and Radiogenic Isotopes

The five samples with the lowest ^{14}C activities occur in wells drilled on drainage divides, whereas the remaining 8 samples do not (Fig. 2.6). Four of these five wells also have the lowest tritium activity (A2.2). These correspondences suggest that waters with the greatest apparent ages tend to occur beneath drainage divides. The term "apparent" is appropriate because the groundwater in the Plateau system is a geographically variable mixture of water recharged incrementally over uncertain lengths of time. Also, residing in a dynamic karst aquifer it is expected that a given mass of groundwater moves to new locations between recharge events and is modified by mixing with fractions of other water masses that have flowed along other paths. As is shown, hydrochemical proxies for relative apparent age can be identified that are available in much greater abundance than ^{14}C data. Maps of such age-related proxies form the basis of interpreting groundwater-age distributions.

Uncertainty in Edwards Groundwater Dating

Groundwater apparent age (or mass age) is the average age of water that contains multiple mass-fractions of groundwaters with different ages. Evaluation of apparent ages is problematic in carbonate aquifers, especially if they are unconfined. The potential contribution of non-radiogenic carbon (^{12}C, ^{13}C) to the groundwater through carbonate-matrix dissolution or oxidation of organic carbon complicates interpretation of groundwater age (e.g., Ingerson and Pearson, 1964; Wigley, 1975) whereby overestimates of age can result. The potential for exchange of ^{14}C for non-radiogenic

carbon along flow paths (e.g., Pearson, 1992) or acquisition of ^{14}C from sources other than natural soil gases also may occur in specific cases, but are difficult to quantify.

That [Ca^{2+}] increases during Edwards aquifer recharge events suggests that most of the dissolution of matrix occurs in the upper parts of the aquifer. What is important about this finding is that the increase in [Ca^{2+}] necessarily includes production of other products of carbonate dissolution, including HCO_3^-. Possible addition of non-radioactive carbon from dissolution in the upper part of the aquifer, including the soil-zone and weathered upper part of the sub-soil area, is expected to cause increases in the apparent age of groundwater.

Previous workers have promoted different methods to correct for the "dead carbon" effect (e.g., Ingerson and Pearson, 1964) while others (e.g., Wigley, 1975) have indicated that the problem is too complex to be addressed by simple solutions such as the $\delta^{13}C$ method introduced by Ingerson and Pearson (1964).

Another consideration with evaluation groundwater age from radiocarbon or tritium is knowledge of their radioactivity at the time of recharge. Analytical results are reported in terms of measured activity in samples relative to established modern values for activity. Radiocarbon analyses are reported as percent modern carbon (pmC) and are based on established standards for modern radiocarbon activity (see Data and Methods section). Uniformity of contemporaneous ^{14}C activity over the time-span of its utility as a dating tool (approximately the last 40,000 yr) is not precisely known, and is less well understood the further into the past we consider. Radiocarbon concentration has been

shown to vary as much as 40‰ over the last 1,000 yr, based on tree-ring data (Lerman and others, 1979; cited in Faure, 1986).

Measurable tritium (^{3}H) activity is an indicator of presence of a significant fraction of modern water (<50 yr) water. Tritium is reported in terms of tritium-units (T.U.), one of which is equal to 7.1 disintegrations of ^{3}H per minute per liter of water (value from Moser and Rauert, 1980; cited in Faure, 1986). There is a wide range of opinion regarding contemporaneous tritium concentrations, which may include an important geographic component. Modern natural concentration of tritium in rainfall probably averages less than 25 T.U., according to Gat (1980). Verhagen and others (1974) suggested that average natural tritium concentrations are closer to 5 T.U. Simpkins (1995) reported tritium concentrations in rainfall ranged from 0 to 44 T.U. (average 11.02 T.U.) in Iowa in 1992. Libby (1954) determined from bottled vintage wines that the annual tritium abundances over a18-yr interval prior to publication were relatively stable when the measured decay rate for tritium was applied. A significant complicating factor is the greatly increased production of both radioisotopes during the years when nuclear and thermonuclear testing was frequent with a peak around 1963 (Verhagen and others, 1974).

Edwards groundwater ^{13}C data show that other factors may be present that complicate interpretation of pmC values. The greatest pmC value in the dataset is 1.002 (A2.2), suggesting that the sample is entirely modern. This same sample also has the greatest tritium activity among the data, a correspondence that supports the conclusion that this water is the youngest in the dataset. However, $\delta^{13}C$ = -8.5‰ PDB for the sample,

which is 18th among the data for most negative $\delta^{13}C$ value (A2.2). The youngest sample might be expected to have the most negative $\delta^{13}C$ signature because it appears to have had the least time to equilibrate with the Edwards marine carbonate matrix whose $\delta^{13}C$ should approach 0‰. It is notable, however, that the sample with the greatest pmC and tritium values also has the lowest Mg/Ca value. This latter observation supports the proposal that Mg/Ca and groundwater apparent age are linked more rigorously than are $\delta^{13}C$ and apparent age.

A critical complication in interpreting groundwater age occurs with mixing between waters of different ages, especially when modern and ancient waters are mixed. This almost certainly is an issue for evaluating unconfined aquifers where groundwater is a mixture that records numerous recharge events with unknown frequencies, intensities, and that may have occurred during times when contemporaneous ^{14}C activities are poorly known. For example, ^{14}C activities were increased significantly over normal levels by nuclear testing in the 1950s and 1960s and it may be difficult to discern the presence of older water if they are mixed with recharge from those times. This situation also may arise when waters of long residence time in a confined portion of an aquifer system emerge from confinement and are mixed with fresh recharge or when two waters of significantly different residence times and traveling different flow paths converge in a confined aquifer.

Young water dominates the ^{14}C activity in mixtures of waters with diverse vintage (Bethke and Johnson, 2008). This is obvious when it is considered that loss of one-half of ^{14}C mass by decay to^{14}N during its first half-life of 5,730 years is significantly greater in

an entirely modern sample than in a very old sample where mass-loss over the same time amount of time is relatively small. With inclusion of a small fraction of modern water in a mixture with very old water the mass of the modern water dominates the total mass of ^{14}C and skews the apparent age toward the age of the younger water in a non-linear way. The effect rapidly accelerates as the age difference of the end-member waters increases.

The effect on ^{14}C apparent age by mixing between hypothetical waters of diverse ages can be quantitatively examined. In this examination the concept of mass-age is important to understand. Each water molecule enters the aquifer system and has a definite residence time. The mass-weighted average of all such inputs is the apparent, or mass-age of the water (Bethke and Johnson, 2008). The ^{14}C activity that each water contributes to the mixture is not in linear proportion to the mass-age, however, owing to the non-linear relationship between elapsed time and ^{14}C activity, given by

$$A = A_o e^{-\lambda t} \qquad \text{(E.1)}$$

where A is the present activity , A_o is the starting activity (approximately 13.56 dpm/g), e is Euler's number (2.71828), λ is 1.209 X 10-4 y^{-1}, and t is elapsed time in years. Half-life for ^{14}C is accepted as either approximately 5,568 y (Libby and others, 1949) or 5,730 y (Godwin, 1962). Both dates are used variously. Apparent ages used in this discussion are based on the "Libby" half-life.

The relationship between pmC and apparent age is given to within 0.06% by

$$\text{Age (y)} = -8032.9\text{Ln(pmC)} - 3.4758 \qquad \text{(E.2)}$$

This relationship can be confirmed empirically by plugging in simple pmC values such as 0.5 and observing that the calculated age (5,568 yr) is approximately the Libby half-life of ^{14}C, that 0.25 pmC produces twice the Libby half-life, etc.

Because pmC is in linear proportion to the mass of ^{14}C (i.e., twice the mass of ^{14}C has twice the activity, thus twice the pmC) the pmC of a mixture of multiple components is the simple average of the pmCs of the components when normalized to concentrations (e.g., activity/L), assuming comparable [C] in each fraction. This allows the direct comparison of ^{14}C apparent age to mass-age of a groundwater mixture. The simplest example of the discrepancy between the two ages is given by the following example.

Consider a 1:1 mixture of two waters. One component is entirely modern with a pmC = 1. The other water is 5,568 y old with a pmC of 0.5. The apparent mass-age of the mixture is (0 + 5,568)/2, or 2,784 years. The average pmC of the mixture is (1 + 0.5)/2 = 0.75, assuming that the modern and pre-modern fractions have the same [C]. Application of the equation given above expressing the relationship between pmC and apparent age gives an apparent age for the mixture of 2,307.4 years. This represents a 17% error in the apparent age and may be considered acceptable, depending on the resolution required in an investigation. The error increases as the difference in component ages increases, however. A 1:1 mixture of a modern water with another water of mass-age 11,136 y (two ^{14}C half-lives) gives a mass-average of 5,568 y and an average pmC = 0.625, the latter of which indicates an apparent age of 3,772 y. This radiocarbon-based apparent age yields an error of 1,796 y, or 33.9% of the mass-age.

The relative proportions of modern and older water of any given age also have calculable effects. Figure 2.10 shows the effects on ^{14}C apparent ages arising from variation in the apparent age of the older component and variation in the fraction of modern water. The chart assumes a 50-y age for the younger water because presence of tritium is a common tool used to detect the presence of modern water, and its limit (due to its brief half-life) is detecting the presence of water younger than about 50 years old.

Figure 2.10 allows determination of the approximate mass-age of a groundwater mixture, given 1) knowledge of the fraction of modern water, and 2) a pmC value that has been corrected for dilution by dead carbon. A practical tool (Mg/Ca) for determining the fraction of modern water in a mixture from the Edwards aquifer in the study area is the result of considerations presented in a following section. Note that the fraction of modern water severely affects the maximum allowable pmC and age of the older fraction that can be detected. For example, a 1:9 mixture with 10% modern water should not have a corrected pmC of less than about 0.1, no matter how old the remaining 90% of the water is. A pmC value of 0.1 corresponds to an apparent age of 18,400 yr. Further, a mass-age of greater than about 25,000 yr would be difficult to interpret even if the actual mass-age was at the 45,000-yr mass-age limit for a mixture of 10% modern water with 90% water of 50,000 yr. The overwhelming influence on radiocarbon apparent age by the younger water mitigates the concern of Bethke and Johnson (2002) that mixing of older water from aquitards with through-flowing younger water in an adjacent aquifer would make the water appear radiometrically older than expected, based on its flow velocity.

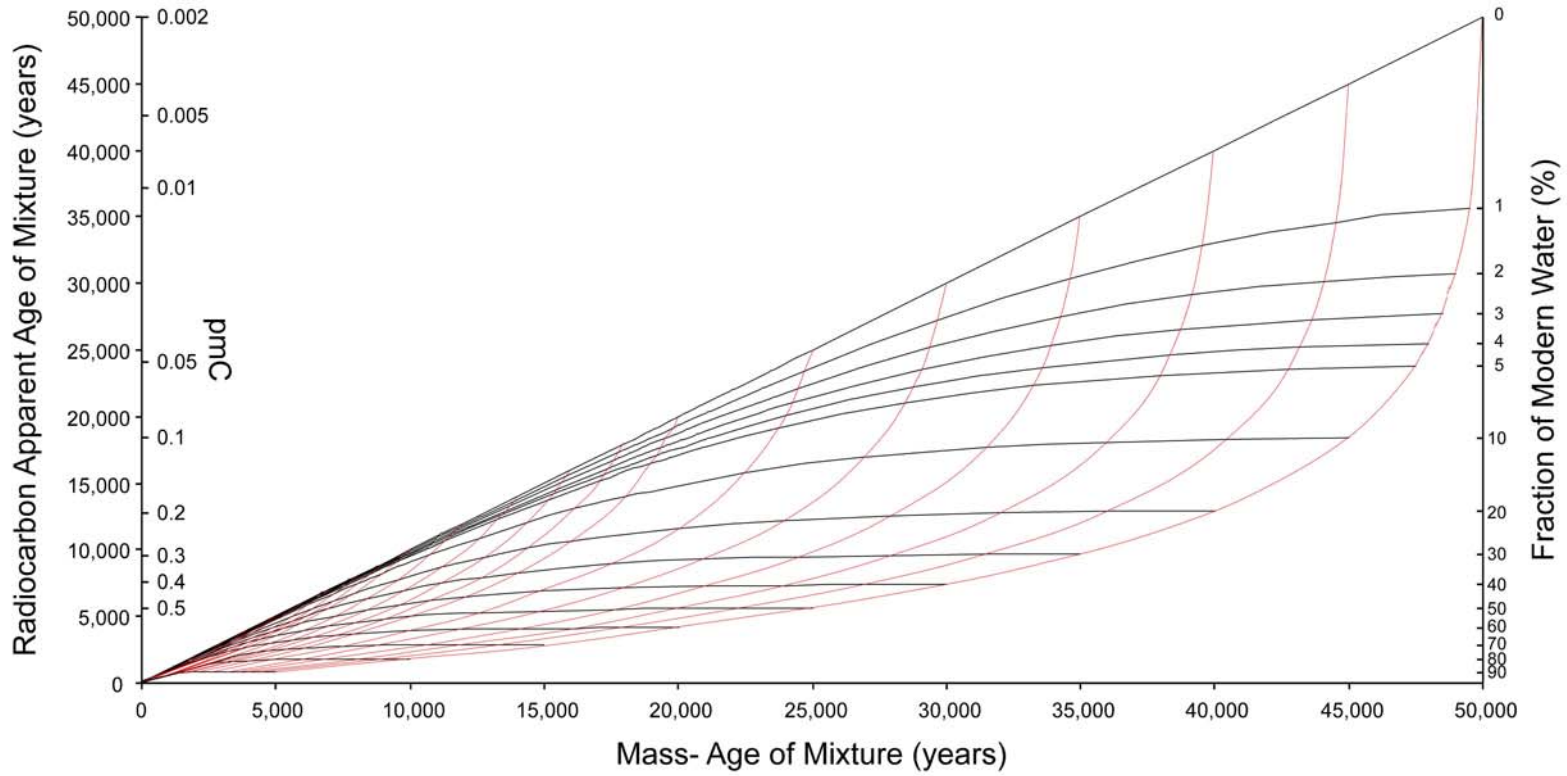

Figure 2.10. Relationships between the fraction of modern (< 50 yr) water, mass-age of mixture between older and modern water, and radiocarbon-based apparent age of mixture. Graph shows that modern water content progressively dominates radiocarbon apparent age as non-modern fraction is dominated by older water. This phenomenon arises from the non-linear relationship between age and radiocarbon mass. Red curves are generated by calculating the resulting apparent ages from mixing of waters of a given mass age with incrementally varying fractions of modern water. Black curves intersect points of identical modern-water fractions on the black curves. 1:1 line reflects mass-age equivalence to apparent age where no mixing of modern water and ancient water has occurred. Mass-age of older fraction is estimated by entering graph on the pmC-axis, following horizontal line to % modern water fraction, then reading mass-age of older fracrtion on x-axis. Even small fractions of modern water can mask relative abundanceof ancient water.

Identifying and evaluating all of the potential complexities of radio-isotope dating of Edwards groundwater is beyond the scope of this paper. The writer assumes that the generally positive correlations between apparent groundwater age given by radio-isotopes, increasing $\delta^{13}C$ values with increasing apparent age and Mg/Ca, and increasing Mg/Ca with increasing apparent age all point to the validity of assuming that Mg/Ca is proportional to the ratio of modern recharge to pre-modern groundwater.

Distribution Patterns and Controls on Mg/Ca

Edwards groundwater Mg/Ca values in the focus area show geographically systematic patterns of distribution (Fig. 2.11). Potential controls on Edwards Mg/Ca include any or all of the following: 1) geographically variable Mg-calcite or dolomite dissolution that tends to increase groundwater Mg/Ca over time; 2) cation exchange where groundwater Mg/Ca may vary with the extent to which it has proceeded; 3) initial carbonate dissolution in shallow parts of the aquifer during recharge that proceeds at higher rates for calcite than for dolomite and tends to lower groundwater Mg/Ca as it mixes with older waters that have dissolved more dolomite; and 4) mixing in geographically variable proportions of groundwaters with diverse origins and chemical evolution histories.

Given that the data for Figure 2.11 represents several decades of sampling from different wells at different times, uncertainty is present concerning whether different map patterns could emerge if all the sampling was conducted simultaneously. It will be shown that there is a relationship between climatic conditions and constituent concentrations and

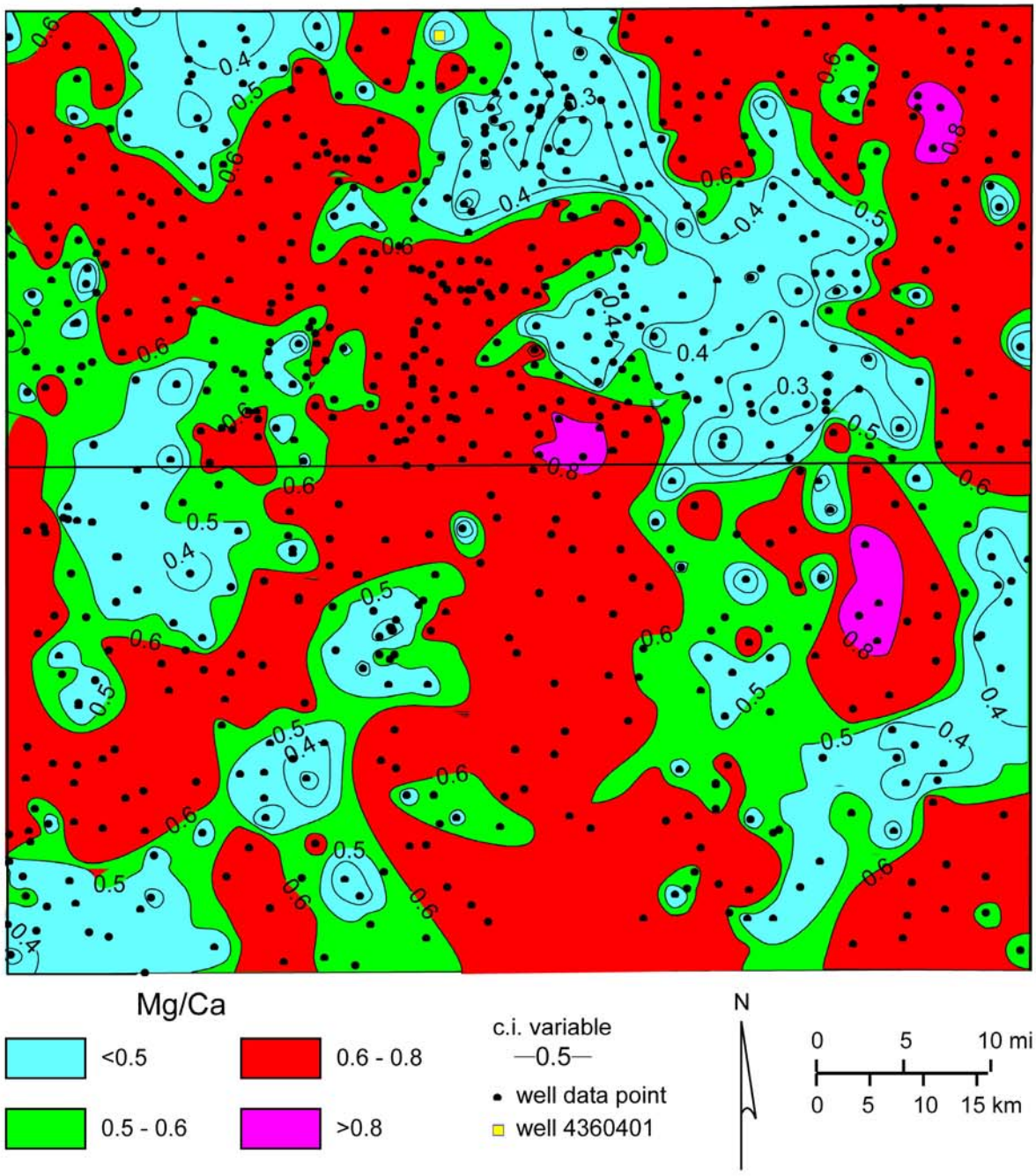

Figure 2.11. Contour map depicting distribution patterns of Mg/Ca values in Edwards groundwater. Lowest values (red) closely correlate to locations beneath drainage divides and, in the northeastern part of area, in more downslope parts of stream networks. Highest values occur beneath upslope parts of stream networks. Also shown is location of well 4360401 (north-central part of area) that has history of sampling shown in Figure 2.13. Data from TWDB (2009).

ratios. However, a close correlation will be shown between Edwards Plateau geomorphology and ranges of Mg/Ca that suggest geomorphic control over the ratio is more significant regionally than most temporal variations that may have occurred since sampling began in earnest in the 1950s.

Mg-calcite or dolomite dissolution

Groundwater Mg/Ca values are expected to increase with groundwater residence time as equilibration is approached between Mg-bearing carbonates and Ca-rich groundwater through congruent and incongruent dissolution processes. Mg-bearing carbonates are abundant in the Edwards aquifer (Fisher and Rodda, 1969; Rodda and Fisher, 1969; Abbott, 1974). Close correlation between Mg/Ca values and pmC values (Figs. 2.7E, 2.7F) is consistent with a hypothesis equating Mg/Ca with apparent groundwater residence time. In a system where water moved through Mg-bearing carbonate it would be expected that the groundwater Mg/Ca would increase with time as congruent or incongruent dissolution of Mg-carbonate occurred. Assuming that matrix composition is held constant, longer groundwater residence times are expected to produce higher Mg/Ca values in the water.

Hydrochemical Responses to Recharge

Relationships described above between pmC, $\delta^{13}C$, and Mg/Ca in Edwards groundwater suggest that Mg/Ca values show a general sensitivity to individual recharge events, periods during which cumulative recharge was more abundant, or when recharge

events were more frequent. To test the potential for hydrochemical responses to climatic conditions a survey was conducted of: 1) water quality from wells that had a history of sampling and chemical analyses; 2) regional hydrochemical trends spanning several decades; and 3) multi-decade climatic changes as reflected in annual rainfall volumes.

For this analysis the hypothesis is proposed that recharge is signaled by an increase in $[NO_3^-]$ in a given well. Use of $[NO_3^-]$ in this way recognizes that the primary source of groundwater NO_3^- (whether anthropogenic or completely natural) is at or near the land surface where NO_3^- production is most active, and that conveyance to the phreatic zone requires movement of NO_3^--bearing water from the surface (recharge). $[NO_3^-]$ is an imperfect quantitative tracer because NO_3^- production may be controlled by temporally variable land use or climatic conditions that may vary in ways not matched rigorously by NO_3^- production rates. Further, variable concentration of rainfall over different geographical areas on the Edwards karst landscape may deliver recharge to a well location with different NO_3^- loads, depending on the relative availability of NO_3^- at different recharge locations. However, survey of over 280 wells in the study area for which historic records were available (TWDB, 2008) and comparison of co-varying hydrochemical data support the conclusion that, in most cases (61%), groundwater $[NO_3^-]$ increases provided signals that recharge had occurred since the previous sampling event. Covariances of $[Ca^{2+}]$, $[Mg^{2+}]$, and Mg/Ca with $[NO_3^-]$ changes are pertinent to the present discussion.

Figures 2.12 and 2.13 represent examples where decreases in Mg/Ca generally are linked to increases in $[NO_3^-]$ (Figs. 2.12), as well as an example where the reverse is

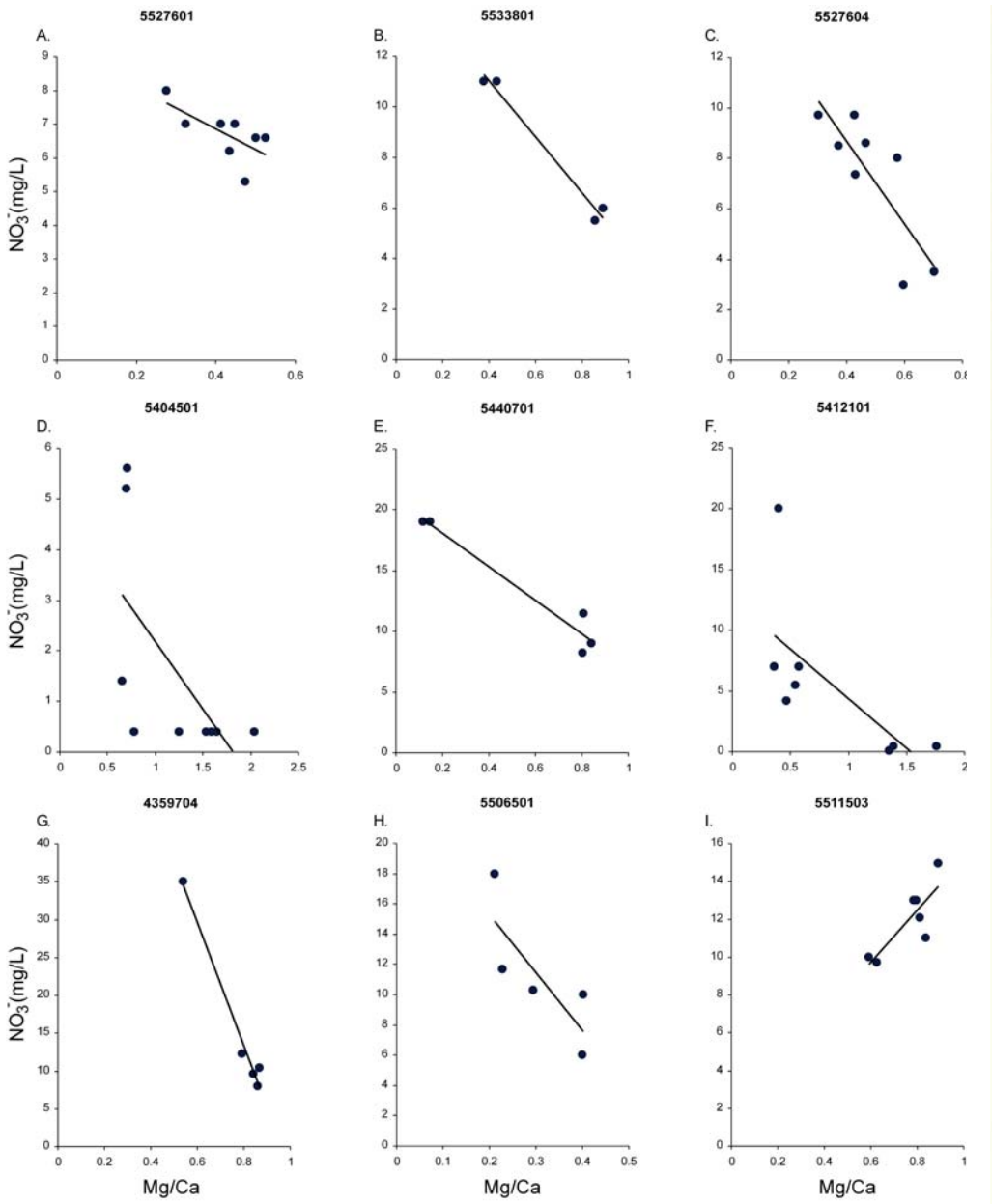

Figure 2.12. Relationships between [NO_3^-] and Mg/Ca for selected Edwards aquifer wells for which four or more historic records were available in the focus area and adjacent Crockett County: A) through C) Sutton County; D) through F) Crockett County; and G) through I) Schleicher County. Approximately 61% of wells for which historic records were available showed correspondences between increased [NO_3^-] and decreased Mg/Ca; 39% showed either poor correlation or a correlation between increased [NO_3^-] and increased Mg/Ca (e.g., I). Positive correlations suggest that increased [NO_3^-] and decreased Mg/Ca are indications that recharge simultaneously transports NO_3- and Ca-enriched groundwater from the surface. This conclusion is supported by the close correlation between Mg/Ca values and groundwater apparent age.

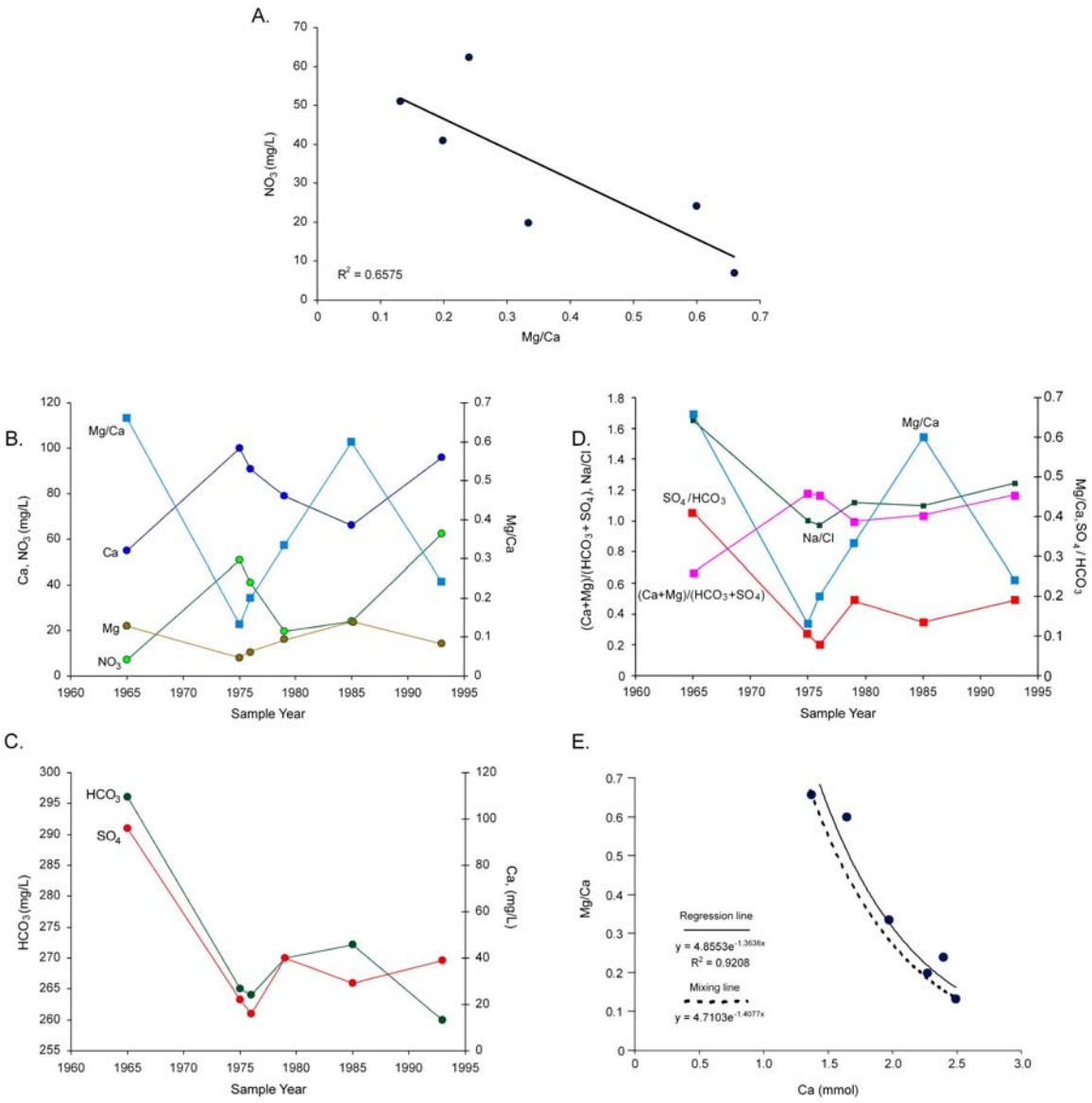

Figure 2.13. Graphs showing variations in hydrochemical constituent concentrations and constituent ratios based on analyses of groundwater sampled from well in northwestern Schleicher County (State well no. 4360401) on six occasions from1965 to 1993: a)[NO_3^-] vs Mg/Ca; b) [Ca^{2+}], [Mg^{2+}], [NO_3^-], and Mg/Ca vs sample year; c) [HCO_3^-] and [SO_4^{2-}] vs sample year, d) covariance of several ratios by sample year, and e) Mg/Ca vs [Ca^{2+}], with regression line and end-member mixing model also shown . Location of well shown in Figure 2.11. Data from TWDB (2008).

true (Fig. 2.12I). The quantitative correlations between [NO_3^-] and Mg/Ca is poor and even show that certain subsets of the data might show an inverse relationship between Mg/Ca and [NO_3^-]. The poor correlation between the three constituents is not surprising because their origins are not directly linked. The nitrogen originates from decomposition of organic material at or near the land surface, whereas the Ca^{2+} and Mg^{2+} originate from dissolution of rock and soil minerals. NO_3^- productivity may vary between recharge events that are of similar magnitude and whose load of inorganic constituents may be similar. Finally, the recharge solution mixes with resident groundwater that is characterized by constituent loads and constituent ratios that reflect a complex history of numerous recharge events and intermixing with waters from diverse flow paths and histories. Therefore, increase in [NO3-] is better thought of a qualitative indicator of recharge.

To illustrate these proposed general relationships between Ca2+, Mg2+, Mg/Ca, NO3-, and recharge, the data from one well will be used which is particularly illustrative of the hypothesis (Fig. 2.13). There are no data from the region where chemical analyses have been produced systematically with corresponding measurements of water levels. Although increases in water levels would indicate recharge had occurred since the previous measurement, a lack of change in water level would not conclusively indicate that recharge had not occurred. Therefore, water level measurements are not necessary to support the hypothesis that corresponding hydrochemical variances can be used to infer recharge.

In Figure 2.13B [NO_3^-] increases are observed to correspond to increases in [Ca^{2+}] and decreases in [Mg^{2+}] and Mg/Ca. The best interpretation for these covariances is that recharge water transports dissolved NO_3^-, dissolves calcite during transit to the phreatic zone causing [Ca^{2+}] to increase, [Mg^{2+}] to decrease, and Mg/Ca to decrease in the resulting mixture of resident and recharge waters. Decrease in Mg/Ca with recharge is consistent with findings of Musgrove and Banner (2004) that Mg/Ca decreases with increases in drip rates in some Central Texas caves in response to increased rainfall. This result suggests that, regionally, more efficient recharge zones might host groundwater with lower Mg/Ca values than would less efficient recharge zones.

Finally, there is a correlation between Edwards Mg/Ca values and $\delta^{13}C$ whereby Edwards groundwater samples with lower Mg/Ca values tend to show more negative $\delta^{13}C$ values (Fig. 2.8C). Water that is fully equilibrated with marine carbonate has an average $\delta^{13}C$ value around 0‰ PDB (Craig, 1954), whereas soil-gas $\delta^{13}C$ has negative values. Most soil-gas is approximately -25‰ (+/- 5‰) PDB (Wickman, 1952; Craig, 1953) and reflects the composition of most plant material from temperate regions, although significantly greater values can be found in plants from arid and semi-arid locations (Craig, 1954). The few soil $\delta^{13}C$ data available from Central Texas are from the Ft. Hood area on the eastern margin of the Edwards Plateau which is underlain by Lower Cretaceous carbonates. Soil $\delta^{13}C$ in the area ranges -20.8‰ to -5.8‰ and averages -19‰ (Nordt and others, 1994). The trend shown in Figure 2.8C suggests that waters with lower Mg/Ca values tend to have $\delta^{13}C$ values that indicate a greater affinity to soil values, whereas waters with higher Mg/Ca tend to have $\delta^{13}C$ values that show greater affinities

with marine carbonate. These correspondences support the proposition that lower Mg/Ca values indicate a greater affinity to recharge than to waters that have resided in the aquifer for a longer time.

Groundwater Mixing

Although controls by dissolution of Mg-carbonate and calcite on Mg/Ca are important in certain phases in the chemical evolution of Edwards groundwater, the final stage in the process is mixing between waters with different origins and different chemical evolutionary histories. Some fractions of Edwards groundwater have characteristics that suggest residence time in the Antlers, or even Permian aquifers (Nance, this volume). Chemical and isotopic characteristics of these fractions, compared with most Edwards waters, are higher salinities, enrichment in SO_4, greater depletion of heavy isotopes of oxygen and hydrogen, higher $^{87}Sr/^{86}Sr$ values, and lower tritium and radiocarbon concentrations. Other fractions in Edwards water are modern recharge waters that have percolated through the Edwards and exhibit generally low Mg/Ca values compared to many in Antlers and Permian waters.

Although the prominence of mixing between groundwaters from Edwards and other aquifers is discussed in Nance (this volume) and was based on statistical relationships, the example from the well history introduced in the previous section demonstrates in some detail how the mixing process might reveal itself in individual cases.

Figure 2.13B is interpreted to show that, during recharge, NO_3^- is transported from the unsaturated zone where organic compounds are available. The change in [NO_3^-] depends on its availability from the surface. [Ca^{2+}] and [HCO_3^-] are produced by calcite dissolution either in the soil zone, on route through the vadose zone, or both. The recharge contains little Mg^{2+} because dolomite, if present en route, takes more time to dissolve than is available during recharge events where dominant flow paths are through highly permeable karst-enhanced fracture or bedding-plane pathways. Mixing of recharge with resident water raises [Ca^{2+}] and lowers [Mg^{2+}], thus lowering Mg/Ca in the mixture. The extents to which these changes occur depend on the relative volumes and chemistry of recharge and of resident water and the extent of intermixing.

Support for the contention that a fraction of the resident groundwater is from siliciclastic aquifers below the Edwards are found in Figures 2.13C, and 2.13D. In Figure 2.13C [SO_4^{2-}] is shown to decline significantly with the influx of recharge. This development is consistent with the dilution by recharge of resident groundwater, the latter of which contains a significant fraction of SO_4-enriched Antlers- or Permian-derived water. This development is also reflected in the corresponding decline in SO_4/HCO_3 (Fig. 2.13D). Notably, [HCO_3^-] also declines during this interpreted recharge signal even though [Ca^{2+}] increases. This is explained by the hypothesis that the [HCO_3^-] reflects [Ca^{2+}] and [Mg^{2+}] in the Antlers or Permian fraction of the resident water prior to cation exchange in their original siliciclastic host aquifers, and preceding their flow into the Edwards. This hypothesis is supported by the corresponding low value of

$(Ca^{2+}+Mg^{2+})/(HCO_3^{-}+SO_4^{2-})$ (Fig. 2.12D) which was suggested in a previous section to indicate cation exchange at values significantly less than 1 (in milliequivalent units).

The apparent maintenance over 19 yr of relatively low measured values of $[SO_4^{2-}]$ and $[HCO_3^{-}]$ in the 1975 sample suggests that return to conditions where SO_4^{2-}-enriched waters from the siliciclastic aquifers reenter the Edwards aquifer may require a protracted period to recur, assuming that sampling has been sufficiently frequent to capture trends that are representative of the 3 decades during which the 6 samples were analyzed. Records of annual rainfall in the region indicate that the earliest sample was taken after several years of below-average rainfall and at the end of a long-term, overall drier period than has characterized the region more recently (Fig. 2.14).

A conservative mixing model can explain the range of Mg/Ca values from the well whose sampling history is depicted in Figure 2.13E. In Ca-Mg/Ca space (Fig. 2.13E) the mixing model between the highest-Mg/Ca and lowest Mg/Ca end-members closely parallels the exponential regression curve for Mg/Ca vs $[Ca^{2+}]$ for the data set. The mixing model concept suggested for this well-specific data can be tested on the larger dataset for the Edwards groundwater on the Plateau. Figure 2.15A shows all Edwards aquifer groundwater data for the focus area in addition to that from an adjacent county (Crockett Co.) in Ca-Mg/Ca space. Superimposed are two curves based on conservative mixing models between, respectively, 1) the sample with approximately the highest $[Ca^{2+}]$ and lowest Mg/Ca values and 2) each of two other samples with approximately the lowest $[Ca^{2+}]$ and highest Mg/Ca values. Over 90% of the data fall within the envelope formed by these two curves. Note also that the general shape of the data pattern in Figure

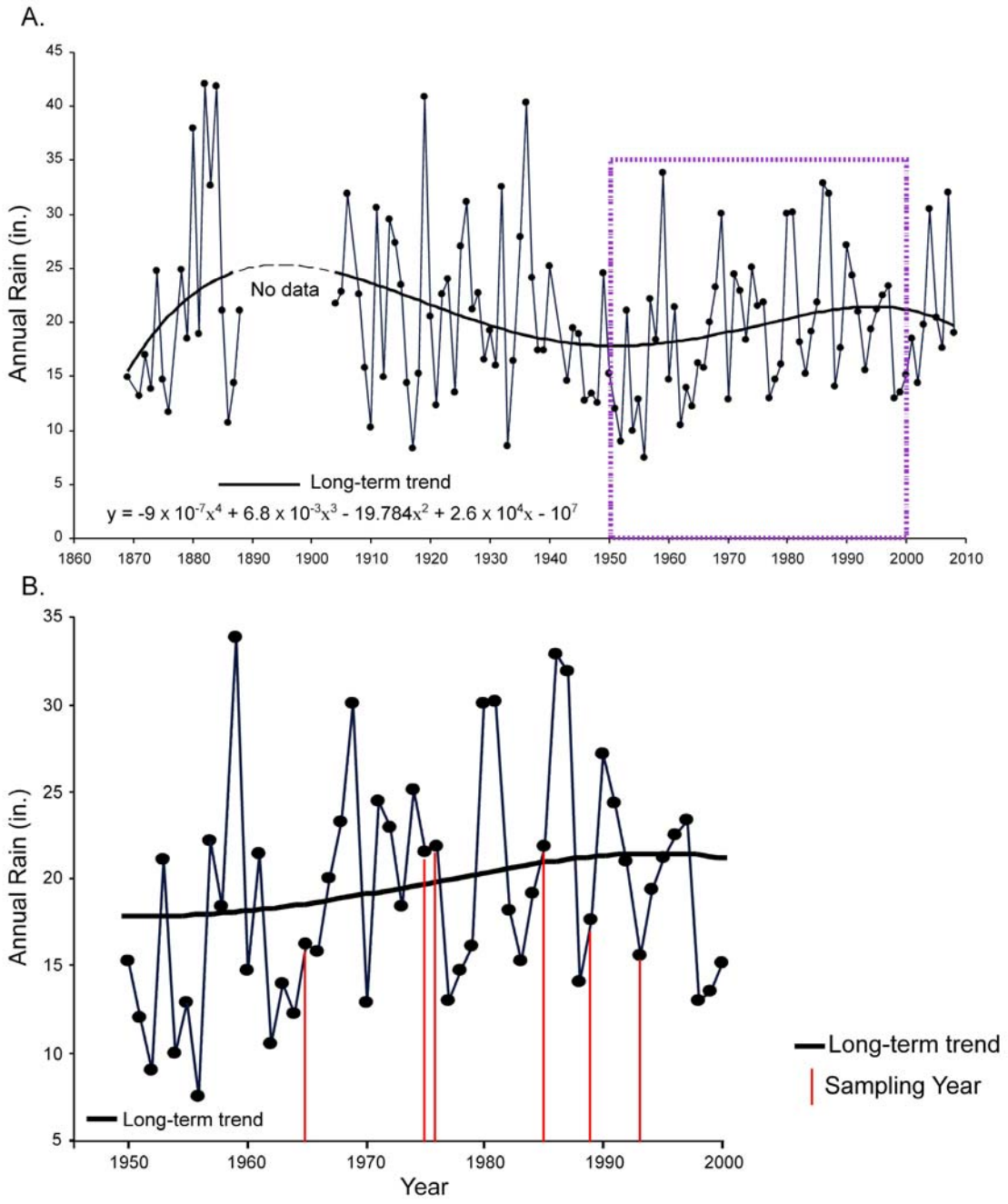

Figure 2.14. Graphs showing variations in San Angelo annual rainfall: A) from 1868 to 2008; and B) detail of data from 1950 to 2000. Also shown in B) are sampling years for selected Schleicher Co. well (Fig. 2.13) and lower-order rainfall trend defined by a 4th-order polynomial regression curve. Note that 1964 sampling of high-SO_4, high Mg/Ca water occurred after several years characterized by below-average rainfall and after a local minimum in the long-term trend.

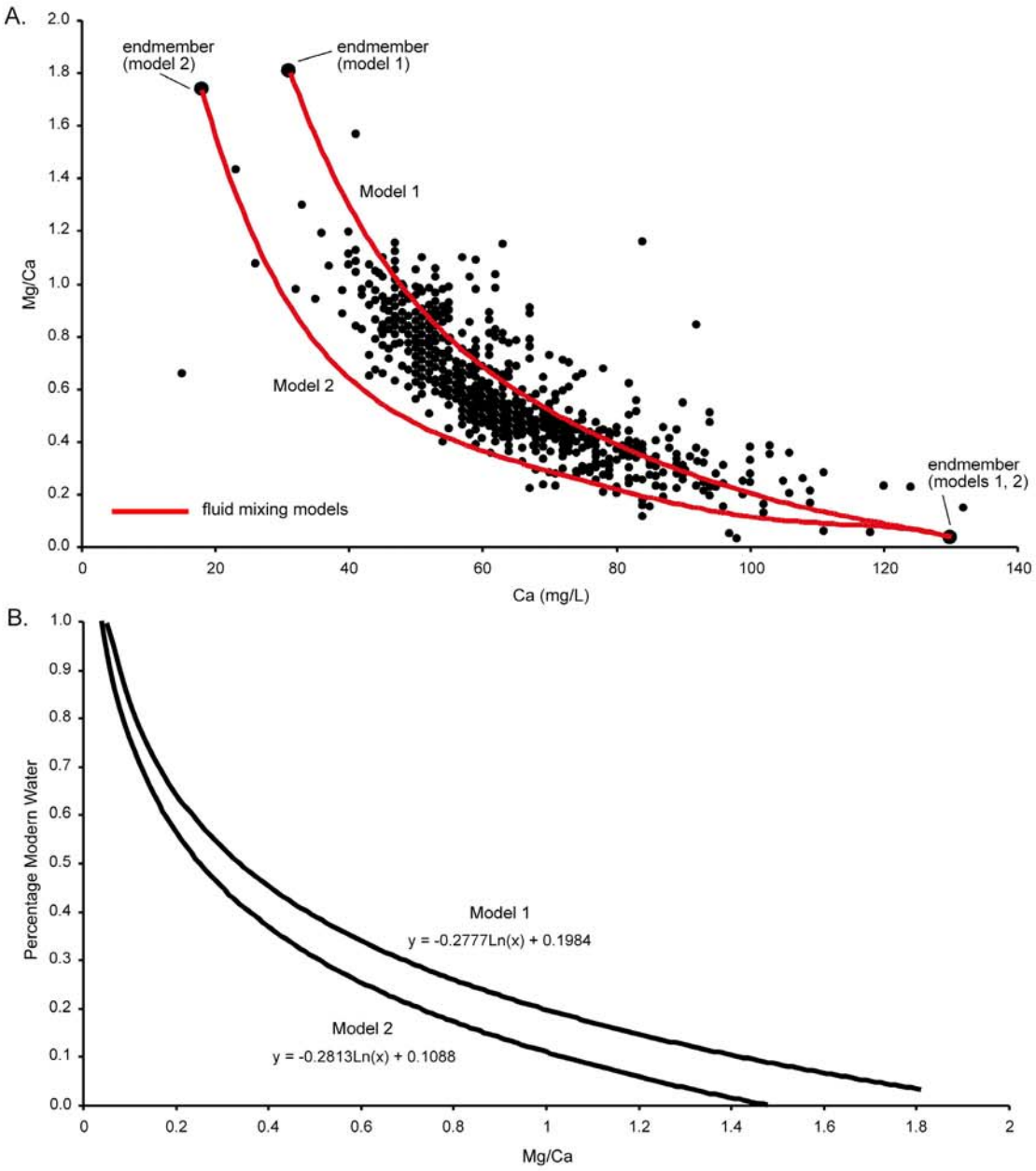

Figure 2.15. Graphs showing A) Ca-Mg/Ca relationships and mixing models (red curves) for Edwards groundwater Mg/Ca end members in the focus area; more than 90% of samples from the Edwards aquifer occur within the mixing model envelope; and B) mixing models from A) in terms of interpreted percentage of lower Mg/Ca waters. The lowest Mg/Ca value is proposed to represent 100% modern water. The difference in the two models is approximately 9% for any Mg/Ca value. Percentage of modern water is based on mixing models, whereby the lowest Mg/Ca value is proposed to represent 100% modern water and highest Mg/Ca is proposed to represent 0% modern water. Model 1 was used to generate the map shown in Figure 2.19. Data from TWDB (2008).

2.15A approximates the trajectories of the mixing curves. A reasonable summation is that the distribution of the data represent mixtures of 1) several end members with relatively low [Ca^{2+}] and high Mg/Ca values with 2) several other end members with higher [Ca^{2+}] and low Mg/Ca values. If the end-member mixing concept is valid for Edwards groundwater then Mg/Ca values indicate relative proportions of the end-member waters. Similar mixing models explain correlations between Mg/Ca and radio-isotope activities. These coincidences will suggest that Mg/Ca can be used as a proxy for groundwater apparent age.

Correlations Between Radio-isotopes, Mg/Ca values, and $\delta^{13}C$

Relationships between radiocarbon, tritium, and Mg/Ca for samples collected for this project from the Edwards aquifer in the study area are depicted in Figures 2.7A and 2.7E. The Edwards aquifer samples cluster between radiocarbon values of 0.07 pmC and 0.7 pmC, tritium values of 0.1 T.U. and 3.28 T.U., and Mg/Ca values of 0.38 and 1.41.

Correlation between radiocarbon and tritium for the complete sample set has an r^2 = 0.771, based on a polynomial regression curve. However, correlation between variables subdivided into smaller geographic areas is much better, ranging from 0.7362 to 0.9254 on a county-specific basis (Fig. 2.7A). The better correlation between pmC and tritium content on an area-limited basis indicates that processes controlling relationships between radiogenic isotopes vary on a geographic and, ultimately, geomorphic basis. Good correlation between pmC and tritium activities suggest that pmC may serve to rank groundwater samples according to relative ages.

A reasonable and potentially useful explanation for the observed relationship between tritium and pmC is that it reflects mixing between groundwater of different ages, some of which might be quite old. The waters with the lowest pmC values have the least amount of tritium, whereas the waters with the greatest pmC have the most tritium (Fig. 2.7A). An explanation for these correspondences is that the oldest waters occur in the poorly circulated parts of the aquifer and are less readily flushed by modern recharge, whereas better circulated parts of the aquifer have overall younger waters and a greater portion of very modern water. A reasonable expectation is that most of the mixing occurs in the uppermost part of the phreatic zone where percolating recharge contacts the water table.

Edwards Mg/Ca values correlate closely with pmC, based on the 32 samples of Edwards groundwater collected for this project (Fig. 2.7E). The correlation between radiocarbon and Mg/Ca has an overall $r^2 = 0.8473$. As with the relationships between radiocarbon and tritium, correlations between Mg/Ca and radiocarbon are stronger within smaller areas, with almost perfect correlation in the northeast part of the study area (Schleicher Co.) where $r^2 = 0.9857$ (Figs. 2.7E, 2.7F). Notably, the regression curve for the data in Figure 2.7E is essentially identical to a mixing model between the extreme Mg/Ca end-members. These coincidences suggest that Mg/Ca values 1) can be used as proxies for relative (not absolute) groundwater age whereby waters with the lowest Mg/Ca are approximately have the youngest apparent ages among the population of available Edwards groundwater data, and 2) Mg/Ca values reflect relative proportions of end-member waters in conservative mixing models.

Waters with greater pmC values tend to have lower $\delta^{13}C$ values (Fig. 2.8). The implications for recharge of $\delta^{13}C$ values and correlated Mg/Ca values are discussed in the groundwater mixing section. Correlation between $\delta^{13}C$ and radiocarbon, which is better than between $\delta^{13}C$ and Mg/Ca (Fig. 2.8), suggests that younger Edwards waters tend to show a greater similarity to soil values than waters with higher Mg/Ca which have $\delta^{13}C$ values more similar to those of marine carbonate. A reasonable conclusion from these correspondences is that waters with lower Mg/Ca values tend to be younger and tend to reflect more recent residence in the soil zone. Therefore, low Mg/Ca waters are influenced to reflect a greater fraction of more recent recharge than do high Mg/Ca waters.

Given this coincidence between inferred recharge events with reduction in Mg/Ca mapping of Mg/Ca may delineate preferred areas for recharge (Figs. 2.11, 2.16). Such delineations are strengthened by geographically coincident geological characteristics that could be reasonably expected to affect recharge efficiency, such as soil permeability or geomorphic characteristics that are common to areas with similar Mg/Ca values.

Figures 2.11 and 2.16 show the distribution of Mg/Ca values within the 2-county focus area. Higher Mg/Ca values tend to occur in bands along topographic divides, the most prominent of which overlies the ridge composed of Upper Washita strata (Fig. 2.2). Soil types upon the Upper Washita are overall the least permeable on the Edwards Plateau (Fig. 2.17) based on the high clay content in the parent material (the Buda and Del Rio Formations) that remains in the soil after the carbonate host rock has dissolved

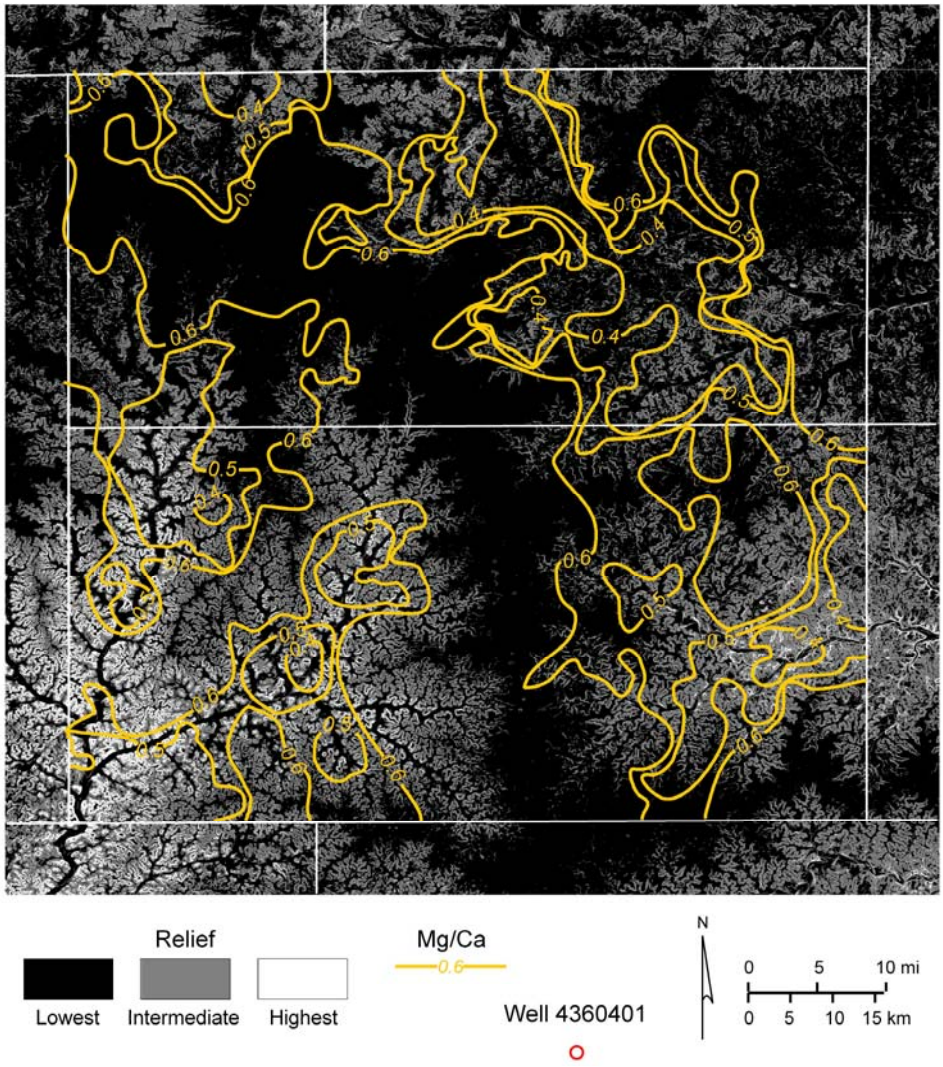

Figure 2.16. Relative topographic relief (slope intensity) in the eastern part of the focus area. Black areas depict relief less than approximately 4m/km and occur on the flat to rolling topographic divide and in the stream bottoms. White areas depict high angle slopes adjacent to incised streams, whereas gray areas depict intermediate slopes. Map generated in ArcGIS from analysis of DEM (USGS, 2008). Also shown is distribution of Edwards groundwater Mg/Ca values (data points are shown in Figure 2.11). Note the coincidence of 1) high Mg/Ca values and northwest-southeast trending topographic divide, and 2) low Mg/Ca values and upper parts of drainage system (gray and white areas). Also note correspondence of divide location and distribution of Upper Washita strata, as shown in Figure 2.2, and low-permeability soils shown in Figure 2.17. Asymmetrical distribution around divide of Mg/Ca values greater than 0.6 in the southern part of area discussed in text. Chemical data from TWDB (2008).

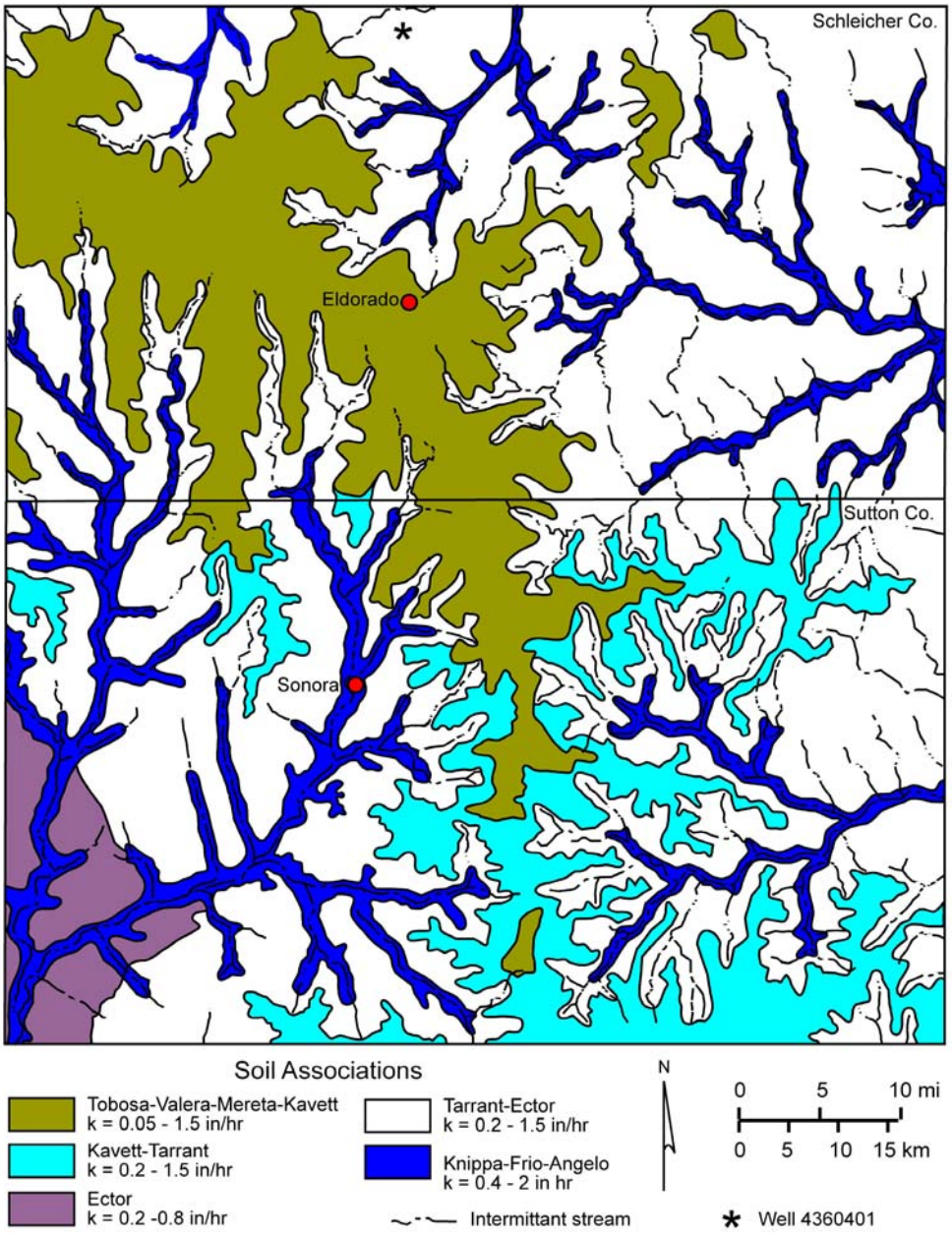

Figure 2.17 Generalized distributions of soil associations in the focus area along the regional drainage divide. Tobosa association soils upon the divide are developed on the clay-rich Buda and Del Rio Formations and exhibit overall lower permeability than do soils in the areas away from the divide where karst features also are better developed on Lower Washita and Fredericksburg strata. Comparison of this map with Figure 2.16 show significant correlation between Mg/Ca values and topographic features (divides, stream networks) in much of the focus area. Soils maps modified from Wiedenfeld and McAndrew (1968) and Wiedenfeld (1980).

by near-surface weathering. Lower Mg/Ca values tend to occur in the losing-stream networks (Fig. 2.16) where karst features are best developed and soils that are formed on the Lower Washita and Fredericksburg strata (Figs. 2.2, 2.17) are more permeable. Notably, the ridge areas where Mg/Ca values are elevated are also approximately the same areas where SO_4/TDS values are highest; and the drainage areas are where the SO_4/TDS values are lowest (Nance, this volume). Nance proposes that the most likely immediate origin of elevated SO_4^{2-} in the Edwards was the Antlers aquifer, although the ultimate source to the Antlers was more deeply buried Permian evaporite-bearing strata. The geographic coincidence of elevated SO_4/TDS and Mg/Ca values suggests that SO_4-enriched water, having previously flowed into the Edwards from deeper formations, is being flushed from the Edwards by modern recharge, and that flushing is most efficient in well-developed drainage areas.

Geomorphic Controls on Distributions of Mg/Ca Values

Mg/Ca distribution patterns are correlated to a remarkable degree with geomorphic features in the focus area (Fig. 2.16). Mg/Ca values exceeding 0.6 (molar units) are conspicuously associated with the regional topographic divide and several secondary drainage divides, whereas Mg/Ca values less than 0.6 forms belts about 20-mi-wide that occupy the upper slopes of the well developed drainage system that is populated by networks of losing streams. Within the focus area Mg/Ca values tend to increase over short distances down slope of the belts of low Mg/Ca values. Given the previous analysis that supports the conclusion that lower Mg/Ca values signal more recent recharge. I

hypothesize that recharge is most efficient in the upper reaches of the drainage networks, and least efficient on the topographic divides and in lower reaches of the drainage networks.

The poor recharge efficiency on the regional divide is explained by overall lower permeability of soils that have developed on the clay-rich Buda Formation of the Upper Washita Group (Figs. 2.2, 2.17), which is argillaceous in its uppermost parts (McKalips and others, 1981). Elsewhere in the Plateau region the Del Rio Formation, which stratigraphically underlies the Buda in those areas, has been shown to the origin of clayey soils (Cook and others, 2007) where the Buda has been removed. However, the Del Rio is reported to be absent in the study area north of southernmost Sutton County (McKalips and others, 1981). Although the divide areas have numerous playa depressions (BEG, 1981) these features are less efficient recharge windows due to the presence of fine-grained sediment in their floors (Pool, 1977) than are the drainages away from the divide areas. Better permeability characterizes the generally clay-poor soils and thinner soils that developed on the clay-poor Fredericksburg and Lower Washita Groups (2) that compose the upper slopes of the generally steeper drainage areas. Some of the most permeable soils occur in the floors of the streams (Fig. 2.17).

Notably, the 0.6-contour hugs the eastern margin of the topographic divide in the southern half (Sutton Co.) of the focus area, whereas it is displaced further to the west along the western margin of the divide (Fig. 2.16). Topographic maps of the area show steeper slopes along the western margin than on the eastern margin (BEG, 1981). Steeper slopes probably reflect the overall southeastern structural dip of Cretaceous strata in the

area which would result in a greater number of strata eroded per depth of erosion along the western side of the north-south-trending divide, whereas less steeply dipping slopes would be more prominent on the eastern side. Therefore, runoff might be more rapid in the west and recharge may be more delayed on the steeper slopes.

Karst probably forms a conduit system that enhances recharge efficiency and is better developed on the Fredericksburg and Lower Washita terrain than on the Upper Washita. Caves are numerous in the Edwards aquifer rocks of the Edwards Plateau (Reddell, 1961; Reddell, 1963; Reddell and Smith, 1965; Smith and Reddell, 1965; Deal and Fieseler, 1975a, b; and Byrd, 1983; and Veni, 1994). In the focus area, caves are found mostly in the Segovia Formation of the Fredericksburg/Lower Washita section, although Ft. Terrett exposures are limited to stream beds in the easternmost parts of the area. However, it is notable that groundwater Mg/Ca values are greater than 0.6 is areas farther to the east. It is possible that the heavily karstified Segovia interval captures most of the recharge, both from direct precipitation and surface run off, in the upper reaches of the drainages and that significantly less surface water is available to the down-slope reaches. Veni and Associates (1991, cited in Veni, 1994) observed that the greatest extent of conduit development on the Stockton Plateau (Edwards-equivalent strata to the west of the Pecos River) was along the contact between the Segovia and Ft. Terrett Formations. If the same relationships hold in the focus area, it is possible that some recharge is returned to surface drainage in the streams where the Ft. Terrett is exposed and that less local recharge enters the Ft. Terrett in those areas than does in more up-slope areas where flow paths are longer along the Segovia-Ft. Terrett contact and more time is available for

recharge to enter the Ft. Terrett. The Ft. Terrett contains the most groundwater-productive interval in the Edwards aquifer on the Plateau (Rose, 1972) and well depths in the area suggest that completions are mostly in the Ft. Terrett section. Therefore, it is reasonable to suppose that it is most readily recharged in the upper reaches of the stream network (Fig. 2.16).

Recharge Model for Edwards Aquifer

The correspondences of certain hydrochemical, isotope, and geologic characteristics of the Edwards aquifer in conjunction with regional decade-scale climatic cycles enable the advancement of a model that explains the geographic and temporal distribution of groundwater constituents in terms general climatic conditions, surface geologic characteristics, cross-formation flow, and the mixing of meteoric recharge with resident groundwater.

Figure 2.18 depicts the proposed Edwards flow system during dry (Fig. 2.18A) and wet climatic conditions (Fig. 2.18B). In comparison to dry periods, wet periods are characterized by 1) a higher water table; 2) more frequent or more intense recharge events; 3) mixing between recharge and resident groundwater over a wider depth range; 4) a lesser proportion of cross-formational flow from the Antlers and Permian aquifers that decreases SO_4/TDS values; 5) lower groundwater radiocarbon apparent ages; 6) more tritium activity; 7) more depleted $\delta^{13}C$ values; 8) higher [Ca^{2+}]; 9) lower [Mg^{2+}]; and 10) lower Mg/Ca values. These characteristics are accentuated in losing-stream drainage networks and more subdued beneath topographic divides. Variations in the

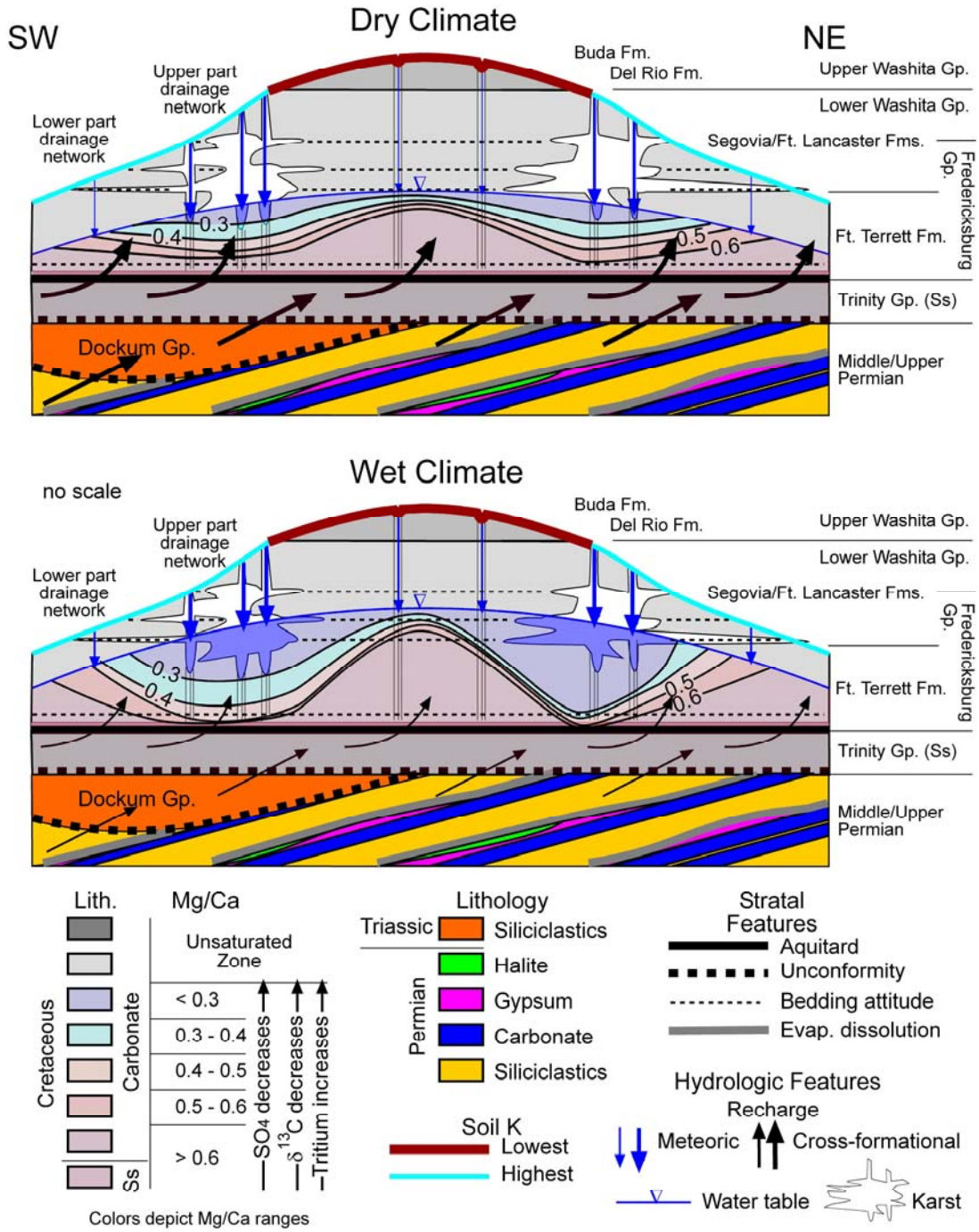

Figure 2.18 Idealized models showing the relationships between geomorphology, stratigraphy, recharge, hydrochemistry, and climate in the Plateau system: A) dry climate model showing low water table conditions, higher gradient for Mg/Ca values, and relatively greater proportion of cross-formational flow from section below the Plateau system than occurs during wetter climatic conditions; and B) wet climate model showing higher water table and overall lower Mg/Ca values. Preferential recharge in upper reaches of drainage network and suppressed recharge on drainage divides is shown.

aforementioned hydrochemical and isotopic characteristics reflect conservative mixing between meteoric recharge and groundwaters in residence, the latter of which exhibits distinct qualities that reflect presence of fractions of water originating from the Antlers and Permian aquifers. Most recharge occurs in the upper slopes of the drainage networks whereas recharge is reduced in the lower reaches of the drainage network.

Application of Mg/Ca Distributions to Groundwater Management Issues

The sum of the hydrochemical, isotopic, and geological data presented above indicate that preferential recharge areas in the Edwards aquifer of the focus area can be identified on the basis of Mg/Ca values as proxies for groundwater age. Further, the apparent validity of a mixing model to explain the range of groundwater Mg/Ca values and relative apparent ages suggests that it may be possible to estimate recharge rates on a local basis that is spatially limited by the distance between wells. If true, these findings may form the basis of groundwater management where abstraction rates are necessarily limited by recharge rates if groundwater resources are to be perpetually maintained. The additional data that is required are total recharge for the study area which may be provided by numerical regional flow models such as that for the Edwards Plateau produced by the Texas Water Development Board (Anaya and Jones, 2008).

Mg/Ca Mixing Model

Given that groundwater mixtures in the Edwards aquifer with the lowest Mg/Ca values are apparently the youngest and that those with the highest Mg/Ca values are

apparently the oldest, Mg/Ca values can be interpreted in terms of %modern water. This interpretation assumes that the lowest Mg/Ca in the Edwards aquifer data set is 100% modern and that waters with higher Mg/Ca contain smaller fractions of modern water, and that water with the highest Mg/Ca is the least modern. A mixing model between water with the lowest Mg/Ca value and water with the highest Mg/Ca (Fig. 2.15) is summarized by the regression equation

$$y = -0.2777\text{Ln}(x) + 0.1984 \quad \text{(E.2)}$$

where x is Mg/Ca and y is percent modern water.

Implicit in the relationship expressed by E.2 is the assumption that oldest waters have dissolved the greatest proportion of Mg-carbonate and the youngest waters have dissolved the least; and that the varying apparent ages in the population of all waters effectively reflect mixing between the end members.

A map was produced to portray regional changes in percent modern water (Fig. 2.19). Mapping and area calculation were performed in ArcGIS. Given a uniform value for recharge volume over the entire study area the following relation is approximately true:

$$x\Sigma A_i P_i = R_s \quad \text{(E.3)}$$

where A_i is an area characterized by a specified range of percent modern water, P_i is the median value within a specified range of percent modern water (pmw), R_s is total recharge volume for the study area, and x is a proportional coefficient required to generate a volumetric unit equal to the flow-model derived recharge volume for the focus area (R_s) and is equal to $R_s/\Sigma A_i P_i = 0.0909$ ft for $R_s = 53{,}000$ acre-ft (6.54×10^7 m^3).

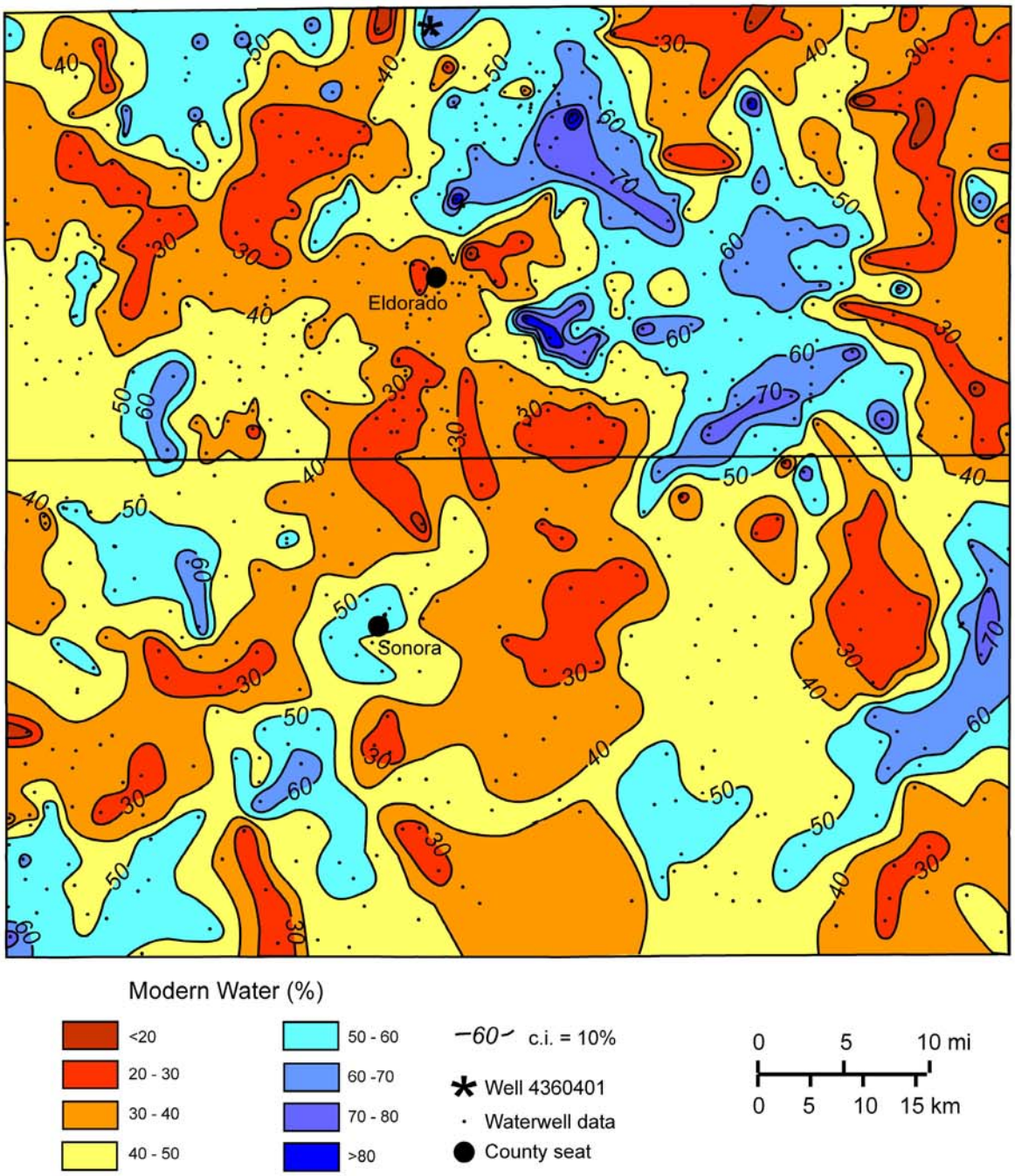

Figure 2.19. Map showing distribution of percent modern water (pmw). Calculations of pmw based on Mg/Ca values and a conservative mixing model (model 1 in Fig. 2.15) between approximately the highest Mg/Ca Edwards groundwater and lowest Mg/Ca groundwater in the Edwards aquifer in the Plateau system. Assuming a compositionally and volumetric uniform influx in water from beneath the Edwards aquifer, the values may approximate relative meteoric recharge rates where the waters with the highest pmw values are the most readily recharged.

Simplifying assumptions implicit in this procedure include throughout the study area 1) chemically and volumetrically uniform influx of water into the aquifer that is not direct precipitation recharge (upward flow from the Antlers aquifer, for example), and 2) a uniform mixing depth in the uppermost part of the phreatic zone. While these assumptions are not readily testable at this time it would be possible to modify this proposed conceptual model to accommodate geographical variations in cross-formational flow and mixing depth.

For this approximation, R_s is 53,000 acre-ft (6.54×10^7 m^3) and is based on results of a numerical groundwater availability model developed by the Texas Water Development Board (Anaya and Jones, 2004) for the focus area. Table 2.1 shows areas and recharge volumes/yr calculated for specified ranges of pmC. These values can be used to estimate allowable pumping rates on a geographic basis that are predicated on politically established desired future conditions in the aquifer. Probably the most significant sensitivity in this application is to the specified overall recharge rate for the study area. However, the objective of the procedure is to demonstrate a method to distribute at local scales specified regional-scale recharge volumes in a reasonably proportional way based on measurable groundwater parameters that show direct relationships to recharge rates. It is a straightforward procedure to integrate changes in regional recharge rates as they are generated by more sophisticated regional flow models, or to modify quantitative relationships between Mg/Ca and pmC.

Table 2.1 Calculated recharge volumes for Edwards aquifer in the focus area

Range (pmw)	Median (pmw)	Area (acres)	Vol (acre-ft)
0-10	5	4,893	22.2
10-20	15	149,517	2,038.7
20-30	25	576,897	13,110.0
30-40	35	626,124	19,920.1
40-50	45	311,612	12,746.5
50-60	55	83,960	4,197.6
60-70	65	13,723	810.8
70-80	75	2,234	152.3
	totals	1,768,960	52,998.2

pmw: percent modern (< 50 yr) water

Summary

Recharge to the Edwards aquifer is proposed to produce hydrochemical and isotopic signals, including increases in $[Ca^{2+}]$, $[HCO_3^-]$, $[NO_3^-]$, pmC, and tritium with coincident decreases in $[Mg^{2+}]$, $\delta^{13}C$, and Mg/Ca. In a hydrochemically closed system, increasing Mg/Ca values reflect a proportional increase in $[Mg^{2+}]$ as groundwater approaches equilibration with Mg-bearing carbonates in the aquifer matrix. However, in an open system such as the generally unconfined Edwards aquifer, the effects of mixing between waters with divergent Mg/Ca values become important in evaluating the significance of the measured Mg/Ca of any sample. Well-specific and regional data show an overall correspondence between climate variability and variability in $[Ca^{2+}]$, $[Mg^{2+}]$, Mg/Ca, and $[NO_3^-]$. The overall greater concentrations of tritium in lower Mg/Ca waters and lower $\delta^{13}C$ in lower Mg/Ca waters both support the proposition that decreasing Mg/Ca is a recharge signal.

Distribution of data in Ca-Mg/Ca-space suggests that mixing between high- and low-Mg/Ca waters can explain intermediate values in the data. In the Edwards aquifer the primary variables in mixing scenarios include the Mg/Ca of the resident water prior to recharge, quantity of recharge, depth of mixing in the phreatic zone after recharge events, relative rates of meteoric recharge versus inflow from other sources, and elapsed time since significant recharge events. The almost temporally and geographically random fashion in which Plateau system groundwater data has been collected, however, make it impossible to quantify most of these effects from the present data.

It is almost certain that higher Mg/Ca values reflect residence for some unknown time of a portion of the groundwater in Mg-bearing aquifer matrix. However, it is also probable that variations in Mg/Ca between samples generally reflects the relative abundance of low Mg/Ca water in an aqueous mixture composed from numerous recharge events that occurred in geographically and stratigraphically diverse parts of the aquifer system.

Viability of radiocarbon as an indicator of Edwards groundwater apparent age is compromised by 1) dilution of the carbon reservoir during carbonate dissolution and 2) mixing between waters of different ages. However, recognition that Mg/Ca values may enable approximation of the fraction of modern (<50 yr) water in mixtures with older waters may allow reduction of the uncertainty of age that arises from the dominance of radiocarbon apparent ages by radiocarbon content of the younger water.

In spite of the questionable utility of using radiocarbon as an absolute dating tool for Edwards groundwater, the correspondence of Mg/Ca and other hydrochemical and isotopic indicators of recharge yields confidence in its viability for ranking geographic locations according to relative recharge efficiency. Further, interpretation of Mg/Ca as a recharge indicator is consistent with corresponding variations in certain physiographic criteria, such as soil permeability, that are known to influence recharge efficiency.

The distribution of Mg/Ca values and their relationship to geographically coincident geologic features shows a co-variation where higher Mg/Ca values tend to occur in wells on the drainage divides and lower values occur away from the divides in more fully developed parts of the surface drainage system that includes numerous

tributaries in a losing-stream network. The evidence strongly suggests that the drainage network composes the primary recharge windows for the Edwards aquifer. Coincidently, wells on the divides tend to show higher values of groundwater SO_4/TDS than do those away from the divides. The best explanation for these correspondences is that recharge is enhanced in areas with higher-permeability and that SO_4-enriched groundwater is more effectively flushed from those areas. The relationship between local topography and Mg/Ca is evident where Mg/Ca and topographic relief are mapped simultaneously (Fig. 2.16). The relationship in the study area is difficult to express statistically because it is not precisely tied to elevation and the relationship occurs in the more upslope parts of the drainage areas. Nonetheless, an overall relationship can be shown between topographic elevation and the magnitude of Mg/Ca values (Fig. 2.20). Drainages are, on average, at lower elevations than elevations on the divides owing to the low structural relief on the resistant carbonate strata that largely control topographic attitude of the divides.

Recognition that that Mg/Ca values reflect systematic mixing proportions between modern and older fractions of groundwater in the aquifer provides a level of predictability that enables evaluation of recharge effectiveness on a local scale determined by spacing between wells for which hydrochemical data is available. Such an evaluation, in turn, enables a reasonable local-scale distribution of recharge volumes that are predicated on specified regional recharge rates in conjunction with local Mg/Ca data. The capability of predicting local variations in recharge rates can facilitate management of groundwater abstraction rates to the extent that they are limited by recharge rates.

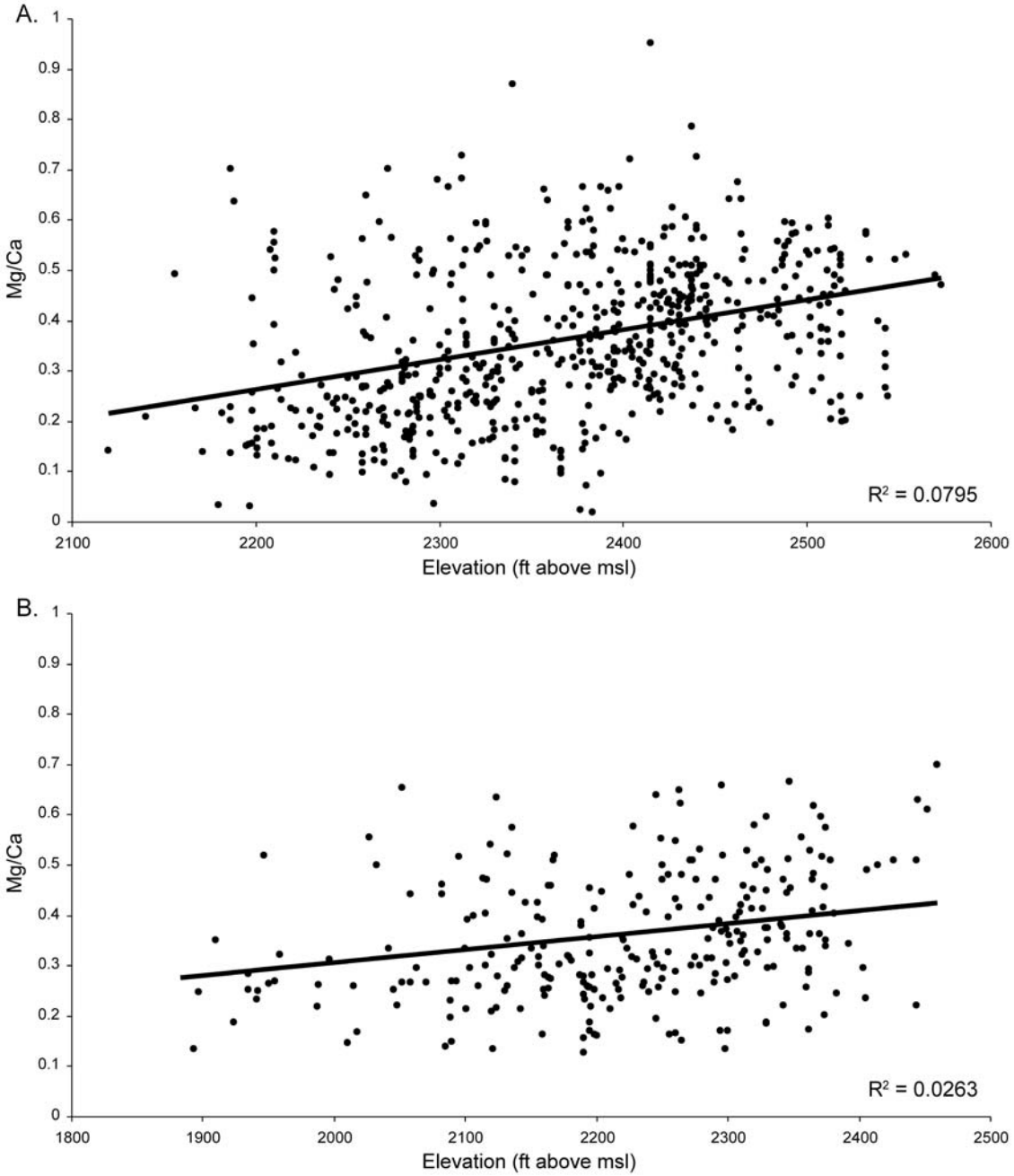

Figure 2.20. Relationship between Mg/Ca values and topographic elevation for the focus area: A) Schleicher and B) Sutton Counties. The negative slopes of the regression lines reflect the tendency of lower Mg/Ca values to occur in drainages downslope of adjacent divides. The generally poor correlation (R^2) is caused by the tendency of these relationships to reflect conditions mainly in the upslope parts of drainages.

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CHAPTER 3

NATURAL MITIGATION OF BRINE-CONTAMINATED STREAM WATER BY BASE FLOW, UPPER COLORADO RIVER, EDWARDS PLATEAU REGION, TEXAS

ABSTRACT

Ratios of chemical constituents can be used to rank the relative significances among multiple subsurface sources of chemical constituents to stream water. To interpret spatial relationships between groundwaters from specific aquifers and Upper Colorado River water historical and new hydrochemical data from water wells and hydrocarbon wells were analyzed. Water-level and pressure data from water wells and hydrocarbon wells, respectively, were used to generate regional shallow-aquifer and deep-brine-reservoir potentiometric maps.

The principal challenges in such analyses are: 1) accounting for as many primary constituent sources as possible, and 2) evaluating the relative contribution of each source at different locations along the stream. While mixing models are can be helpful in illuminating causes for relationships between hydrochemical data, the choice of constituents for modeling may reveal origins of certain hydrochemical components but underemphasize the origins of others. It is shown that constituent ratios such as elevated SO_4/Cl and Ca/Cl values are consistent with the contribution to surface water of groundwater that has migrated through Cretaceous-, Triassic-, and Permian-host aquifers while other ratios such as depressed Br/Cl and elevated Na/Ca values are consistent with contributions from Permian shallow halite-dissolution zones or from Permian and Pennsylvanian deep-brine reservoirs.

Upper Colorado River water contains contributions from: 1) Permian-, Triassic-, and Cretaceous-host aquifers; 2) dissolved Salado Formation halite; and 3) deep-reservoirs hosted in Permian and Pennsylvanian strata. The fraction of brines generally diminishes with distance downstream with local reverses in the trend in the vicinity of oilfields, while contributions from shallow Permian and Plateau system aquifers become increasingly important. These changes are reflected in decreasing along-flow values of TDS, chloride concentration, and Na/Ca; and increasing values of Br/Cl, SO_4/Cl, HCO_3/SO_4, B/Cl, and Ca/Cl. Overall reduction in salinity may also be influenced by recharge rate increases arising from increased annual rainfall volumes with downstream distance.

The river is divided into three hydrochemically characterized segments. The upstream segment exhibits qualities that are interpreted to reflect contributions from, in order of decreasing influence, a) shallow groundwater from Cretaceous and Triassic host aquifers, b) deep- reservoir brines similar to produced waters in the region, and c) brine generated from the meteoric dissolution of shallow Permian halite. The middle segment is characterized by a) an increased influence by shallow groundwater originating from the Cretaceous-host Plateau aquifer, b) significantly diminished influence of halite-dissolution brine, and c) a waning but significant influence of deep- reservoir brine, especially locally. The downstream segment is characterized by dominance of Plateau- and Permian-host groundwater, with conspicuous contributions from dissolved Permian sulfate-evaporite.

Potentiometric surfaces from Lower Permian reservoir intervals indicate a potential for upward flow of brine which may occur through fractures or wellbores, especially in the topographically depressed area associated with the river course. Abandoned surface brine-disposal pits and refining sites are other potential sources of brine. These inputs are most numerous in more upstream segments of the river which traverse prolific Permian Basin oilfields and associated refining operations and brine-disposal sites.

INTRODUCTION

Quality of surface water and groundwater are intimately related. Except for runoff associated with rainfall events, all other natural fluxes into surface-water bodies are through groundwater interflow and base flow. Groundwater quality reflects water-rock interactions within an aquifer system and mixture with fluids from other aquifer systems. Surface water reflects the mixing of water from all inputs associated with the water body. For streams in contact with hydrochemically diverse aquifers along its path surface water hydrochemistry evolves downstream to reflect the inputs of groundwater from each aquifer it traverses. Investigators of groundwater-surface water interaction should recognize that groundwater from individual aquifers that are traversed by streams may have complex histories, including intermixing of groundwater and surface water from multiple sources. The Upper Colorado River basin (Fig. 3.1) in semi-arid West Texas, which undergoes chemical evolution conspicuously along it path, is an ideal laboratory in which to observe and interpret this process.

Counties

B	Borden	G	Glasscock	M	Mitchell	S	Scurry
C	Coke	H	Howard	N	Nolan	St	Sterling
Cn	Concho	I	Irion	R	Reagan	T	Taylor
F	Fisher	J	Jones	Rn	Runnels	TG	Tom Green

Figure 3.1. Map showing location of Upper Colorado River study area in West Texas. Also highlighted as focus area for surface- and groundwater hydrochemical investigation.

The contaminants to water, especially if they have multiple origins, may not be associated always with origin-specific tracers that allow unambiguous identification of their source. Rather, all the available evidence must be integrated to provide the best interpretation of contaminant sources. Once the initial analyses are completed and interpretations of contaminant sources are made, it may be possible to design a program to better resolve sources and develop remedies if so desired.

In a river system part of the overall analysis must include recognizing the causes of chemical changes in the stream as it traverses the landscape. This study was focused on analyzing the causes of hydrochemical evolution in the Upper Colorado River over a greater than 150-mi (241-km) segment in West Texas where it traverses hydrocarbon-producing areas and contacts several aquifers whose mineralogical compositions and present environmental contexts are diverse. Upper Colorado River chemistry undergoes multiple changes along its course that can be attributed to inputs from identifiable sources. Interpreting constituent source-to-sink processes is necessarily an exercise where considerable analysis is required for each of the sampling measurement locations along the river.

Upper Colorado River (West Texas) salinities frequently exceed regulatory standards for drinking water. For example, the 15,893-acre (6,432 hectacre) E. V. Spence reservoir in Coke County impounds surface water from the Upper Colorado River (Fig. 3.1). The watershed upstream of the reservoir includes 15,278 sq. mi. (39,570 km^2) in Texas and New Mexico. With increasing frequency, constituent concentrations in the reservoir have exceeded Texas Commission on Environmental Quality (TCEQ) standards

for chloride (950 mg/L), sulfate (450 mg/L), and total dissolved solids (1,500 mg/L) (TCEQ, 2003). During the sampling phase of this study (2005) of the Upper Colorado River, maximum concentrations (mg/L) measured 3,950 for [Cl^-], 1,500 for [SO_4^{2-}], and 8,430 for [TDS]. Time-series data that report daily fluctuations of salinity in terms of specific electrical conductivity (SC) indicate that SC values at the continuously monitored station on the Upper Colorado at Ballinger, TX are frequently near or greater than 4,000 μS/cm, which corresponds to greater than 2,000 mg/L TDS.

Most previous studies (e.g. Slade and Buszka, 1994) suggest that saline surface and groundwater in the upper Colorado River area has been affected by (a) dissolution of Permian-age strata-bound and recent soil-zone evaporites and (b) formation water released from oilfield operations in the Permian Basin. However, no one to date has tracked and interpreted in detail the apparently systematic downstream hydrochemical evolution of the Upper Colorado from its headwaters in Borden County to the margin of the study area in southeastern Runnels County (Fig. 3.1).

Hydrogeological Setting

Potentiometric Surface and Stream Flow

The potentiometric surface of groundwater in the study area ranges from over 2,945 ft (897.6 m) in the northwest in Borden County to 1,528 ft (465.7 m) in the most downstream part of the Upper Colorado River in Concho County (Fig. 3.2). The potentiometric surface mimics the overall topographic patterns and the positions of larger streams. The elevated hydraulic gradients on the northeast and southwest sides of the

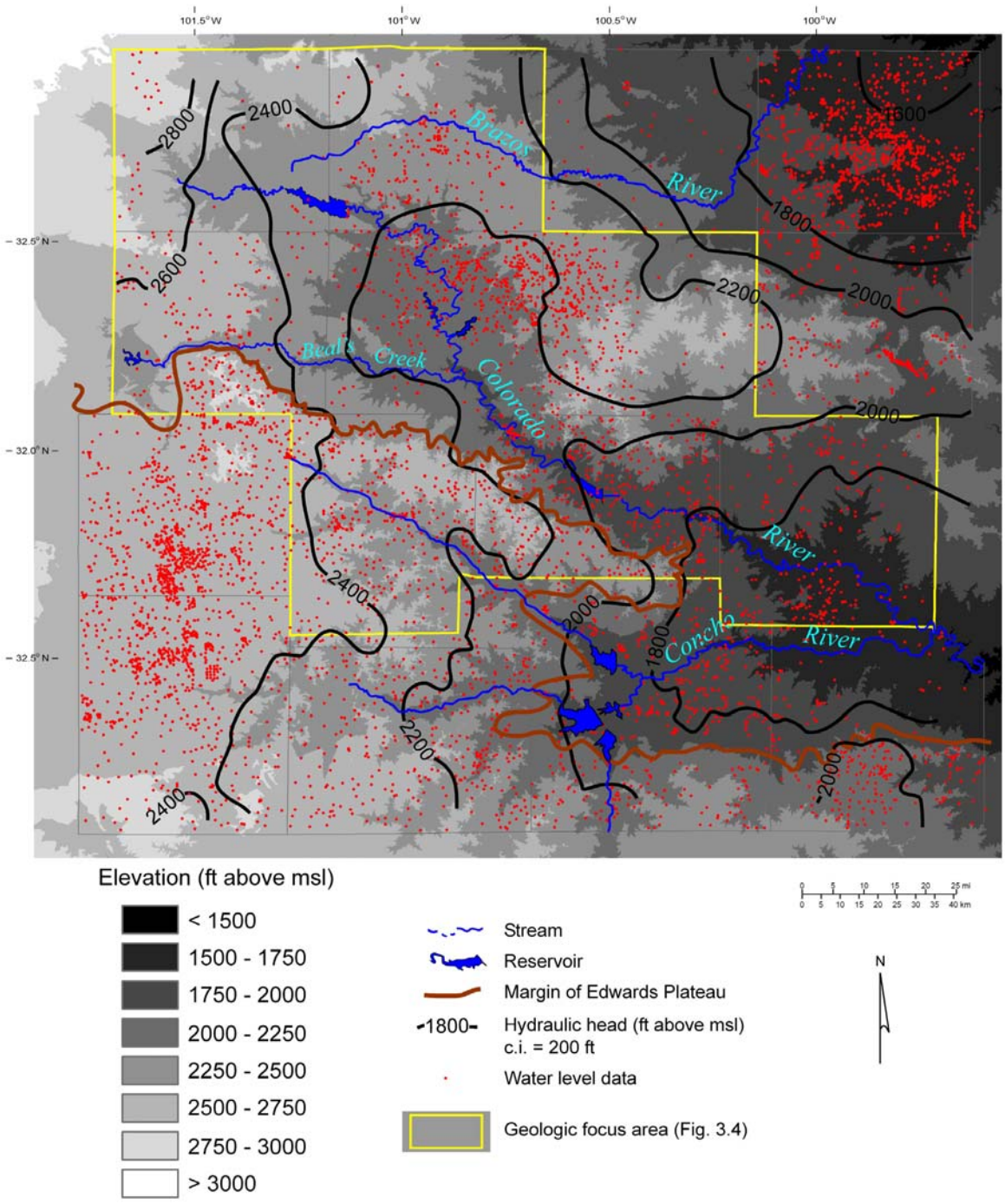

Figure 3.2. Map showing topography and major drainage features in the study area. Margin of Fredericksburg rocks (Plateau aquifer) is marked by heavy brown line. Re-entrant in southeastern part of area is the Concho River valley. Also shown is the potentiometric surface of the shallow aquifers based on water level data from TWDB (2007) which reports most recent data available for individual wells since 1960. Control points for potentiometric map are shown.

river reflect the steep topographic gradients between the stream and the drainage divides, one of which separates the Colorado River valley from the Concho River valley; and the other of which separates the Colorado River valley from the Brazos River valley. Although the Colorado River is a gaining stream most of the time, flow in the study area can be elevated episodically over normal flow by several orders of magnitude (Fig. 3.3A) resulting in stream loss to temporary bank storage. The configuration of the potential field is such that discharge from the Plateau should be expected to take approximately the shortest paths from the divide to the river.

Although the Upper Colorado stream discharge is modest, with an annual median of 62 cfs (1.76 m^3/s) at Ballinger in Runnels County, it can vary considerably on an annual basis (Figs. 3.3A, 3.3C). During extreme flood stage it has exceeded 45,800 cfs (1,300 m^3/s) (U.S.G.S., 2009). Although stream salinity is often expected to decrease with elevated discharge rates, Upper Colorado River salinity is only loosely related to average discharge rate (U.S.G.S., 2009) (Fig. 3.3B). Elevated stream salinity can occur during above-average flows owing to buildup of soluble evaporite minerals in the unsaturated zone during extended periods of depressed rainfall, which contributes to stream salinity during high runoff events and by interflow after runoff has subsided. The impact of this contribution is related to secondary variables, including runoff intensity, time between soil-flushing events, the salinity of water that is stored in banks during flood events, and the rate of discharge from aquifers (base flow). Relatively high discharge events sometimes may be expected to produce highly saline stream water if there are elevated evaporite concentrations in the near-stream parts of an aquifer or in the

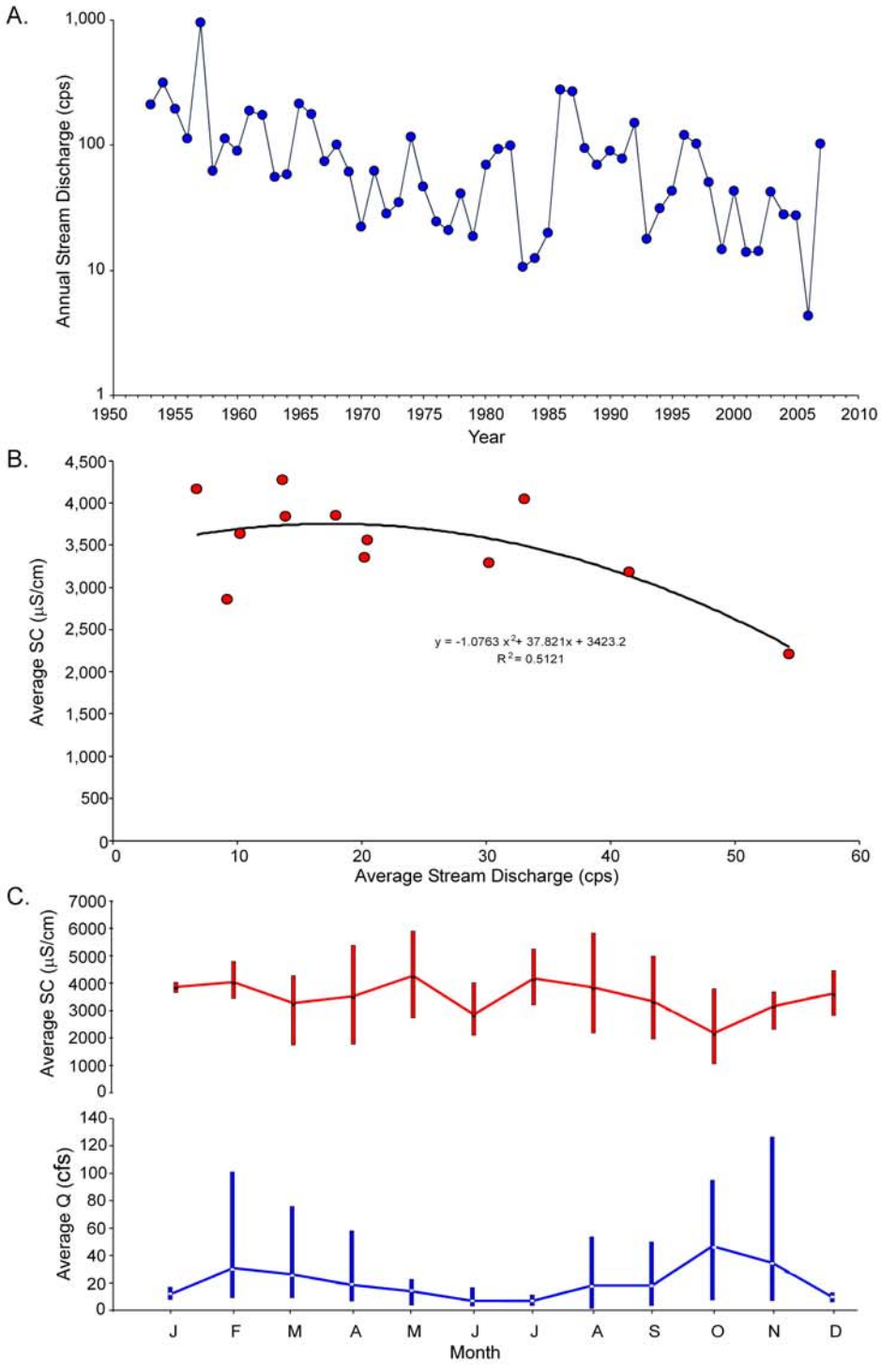

Figure 3.3. Graphs showing, for measurements of Upper Colorado River at Ballinger, Texas A) average annual stream discharge for 1953-2007, B) relationship between average stream discharge and specific electrical conductivity for 2001-2005 (U.S.G.S., 2009) based on monthly averages, and C) ranges and average values of discharge (Q) and electrical conductivity (SC) on a monthly basis.

soil. Whereas a lower-discharge event may be expected to produce lower salinity water if the elapsed time since the last flood has been insufficient to produce high soil salinity. Finally, soil moisture in place immediately prior to rain events, in combination with rainfall intensity, controls runoff intensity. Soil moisture is related not only to the elapsed time since the most recent rainfall, but also conditions of temperature and relative humidity that precede runoff producing events. It is significant that the stream samples used for this study were collected when base flow conditions prevailed.

The Upper Colorado River has its headwaters in the northwestern extreme of the study area and traverses Triassic and Permian-age strata (Fig. 3.4) that contain aquifers contributing base flow to the stream. The largest designated aquifer, the Triassic-aged Dockum aquifer, is classified as "minor" aquifer in Texas (Ashworth and Hopkins, 1995), a designation that understates its significance as a groundwater resource to large areas in the region. Permian system aquifers are composed of a wide assortment of rock types, including halite and gypsum (Fig. 3.5) which are notably soluble in groundwater (e.g., Gustavson and others, 1980; Lowenstein, 1988).

Seventy percent of the surface- and groundwater discharge from the 23,400 sq. mi. (60,606 sq. km.) Edwards Plateau, a Cretaceous-age aquifer system that bounds the Colorado River basin on its southern side, flows to the Colorado River basin (Walker, 1979; Nance, this volume). Although the Colorado River does not contact Plateau aquifers in the study area, groundwater flow from the Plateau discharges to the river through intervening pre-Cretaceous aquifers or via tributaries that originate on the Plateau (Fig. 3.4).

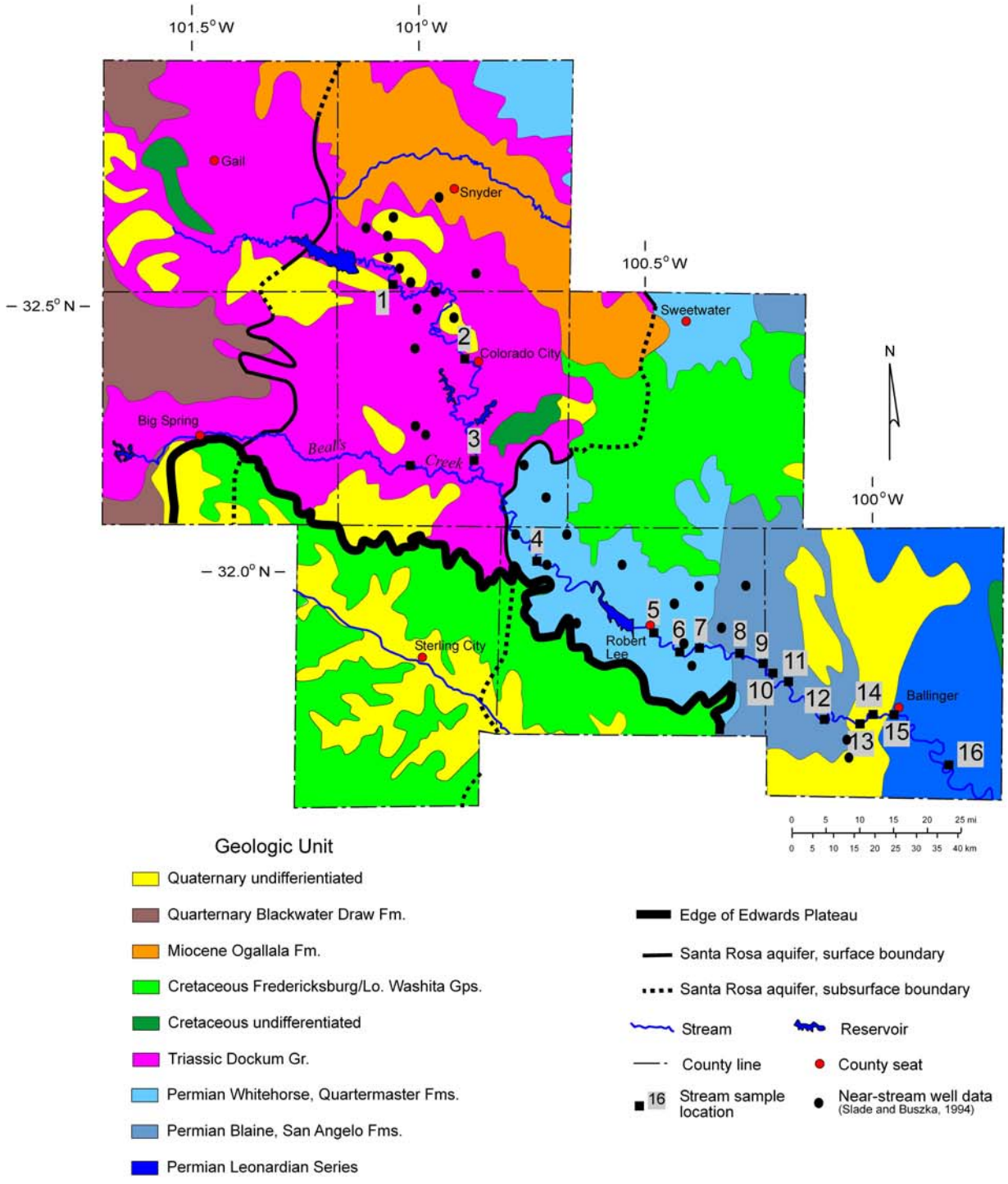

Figure 3.4. Simplified surface geologic map of the study area. Also shown are the margin of the Edwards Plateau (thick line) and boundary of the Santa Rosa sandstone aquifer (dashed line). Note that both Santa Rosa and Permian aquifers are subjacent to the Plateau aquifer in the south-central part of the area. Geologic data from BEG (1992). Santa Rosa subsurface projection from Ashworth and Hopkins (1995).

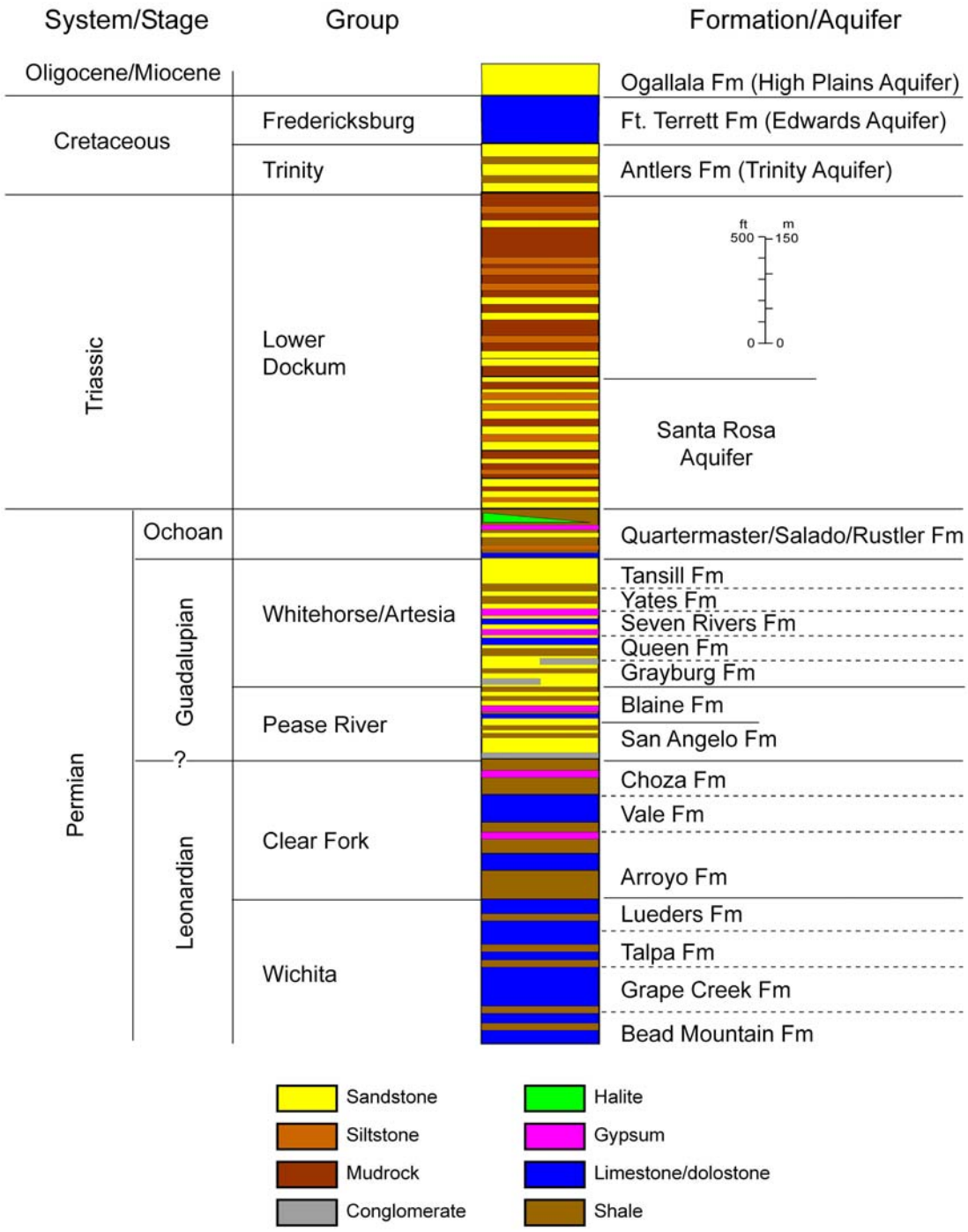

Figure 3.5. Simplified stratigraphic column showing hydrostratigraphic units in the study area.

The Upper Colorado basin and surrounding region is located along the northeastern margin of the petroliferous Permian Basin where thousands of hydrocarbon wells have been drilled and have been producing since the late 1920's. Although environmental regulations have vastly improved over the years the region has a considerable legacy of industrial contamination, especially with regard to disposal or leakage of deep- reservoir brines (a.k.a., produced water) (Walker, 1979; Slade and Buszka, 1994).

The study area ranges in elevation from 1,381 to 3,094 ft (421 to 943 m), the highest elevations occurring on the Edwards Plateau and Southern High Plains in the southwest and northwest corners of the area, respectively; the lowest in the Colorado River valley in northeastern Concho County (Fig. 3.2). Study area climate, from east to west, ranges from semi-arid to sub-humid. In the Upper Colorado River study area rainfall ranges from 16 to 24 in/yr (406 – 610 mm) (Larkin and Bomar, 1983) (Fig. 3.6). Differences between wettest and driest years range from 7.4 to 42.1 in. (188 – 1,069 mm) based on records from San Angelo in Tom Green County (Fig. 3.1). Summers are hot (avg. high 95^{o}F in July) (35^{o}C) and winters are mild (avg. high 59^{o}F in December) (15^{o}C); extremes range from 111^{o}F to -2^{o}F. (43.9^{o}C to –18.9^{o}C) (Weather.com, 2009).

Aquifer Systems

The study area includes aquifer systems hosted in strata ranging from Early Permian to recent in age (Figs. 3.4, 3.5). However, only three of these systems are likely to have an impact on the hydrochemistry of the Upper Colorado because they are either

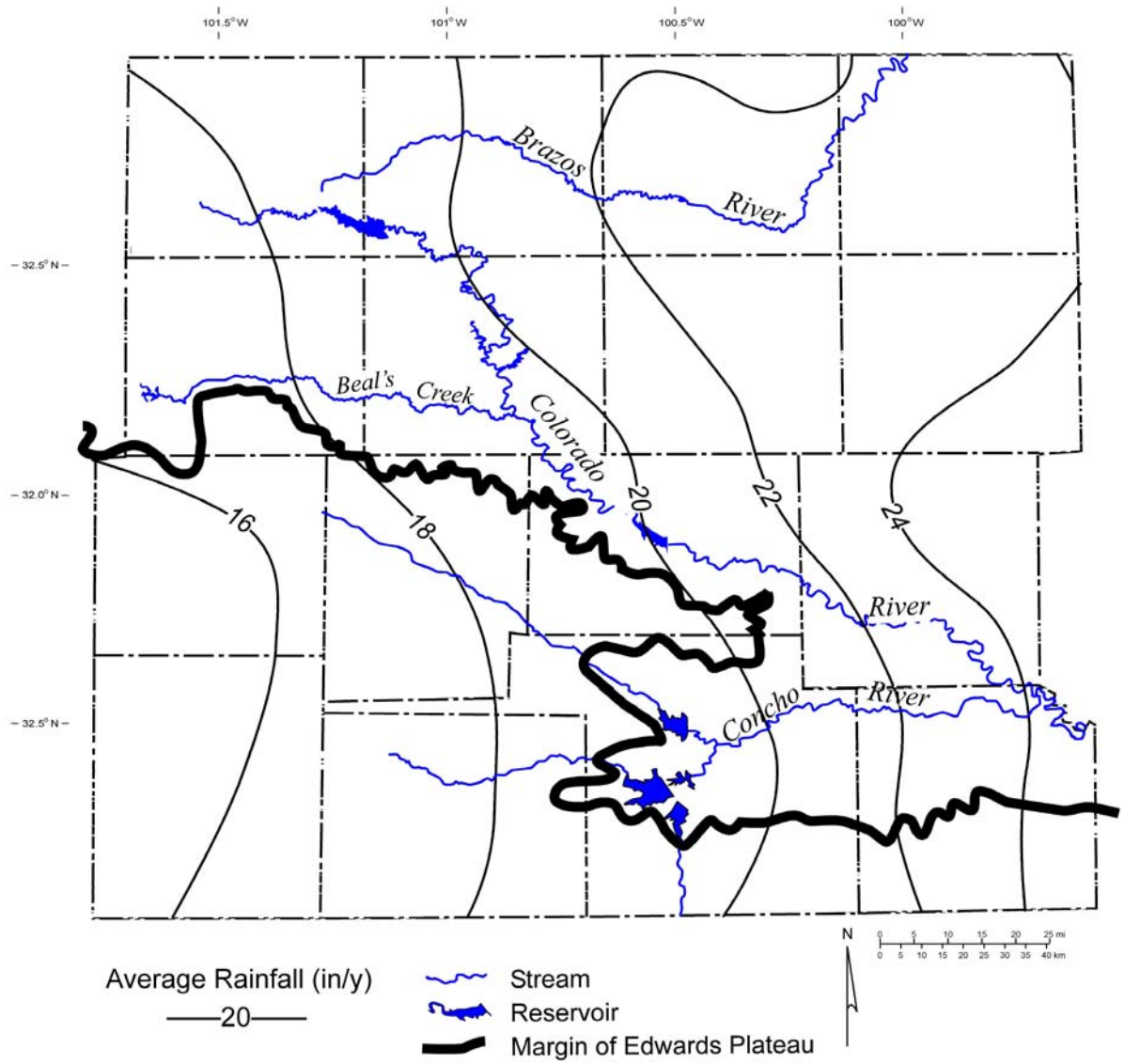

Figure 3.6. Map showing mean annual rainfall for the Upper Colorado River study area. Also shown are the county outlines and major streams and reservoirs from which samples were collected and field measurements were performed for this project. Rainfall data from Larkin and Bomar (1983).

in direct contact with it (Dockum and Permian aquifers) or are very large and nearby (Plateau system). Within the Permian aquifer system, the Salado Formation (Figs. 3.5, 3.7) is especially important as a potential source of high salinity water. A component in regional groundwater composition that also must be considered is Upper Paleozoic deep reservoirs that contain numerous Permian Basin hydrocarbon deposits and great volumes of brine.

Plateau Aquifer System

The 23,400 sq. mi. (60,606 sq. km.) Plateau aquifer system composes the southwestern margin of the Upper Colorado River valley in the study area and comprises several flat-lying sandstone-dominated and carbonate-dominated intervals within the Lower Cretaceous Trinity, Fredericksburg, and Washita Groups (Fig. 3.5). Maximum saturated thickness is over 800 ft (244 m) thick in the Plateau interior (Ashworth and Hopkins, 1995). Edwards Plateau elevation ranges from approximately 1,000 ft to 3,400 ft (305 m to 1,035 m) above mean sea level and stands a maximum of 600 ft (183 m) above the nearest location on the Colorado River in the study area. An approximate 200-ft (61 m) hydraulic gradient over 8 mi (13 km) exists in the same area (Fig. 3.2). The Plateau system is underlain by Triassic and Upper Paleozoic units and overlain by Cenozoic to recent units (e.g., Nativ, 1988), all of which extend into the study area. More details of the Plateau system are found in Barker and Ardis (1996) and Nance (2009a, 2009b, this volume). The Plateau system Antlers sandstone-dominated aquifer of the

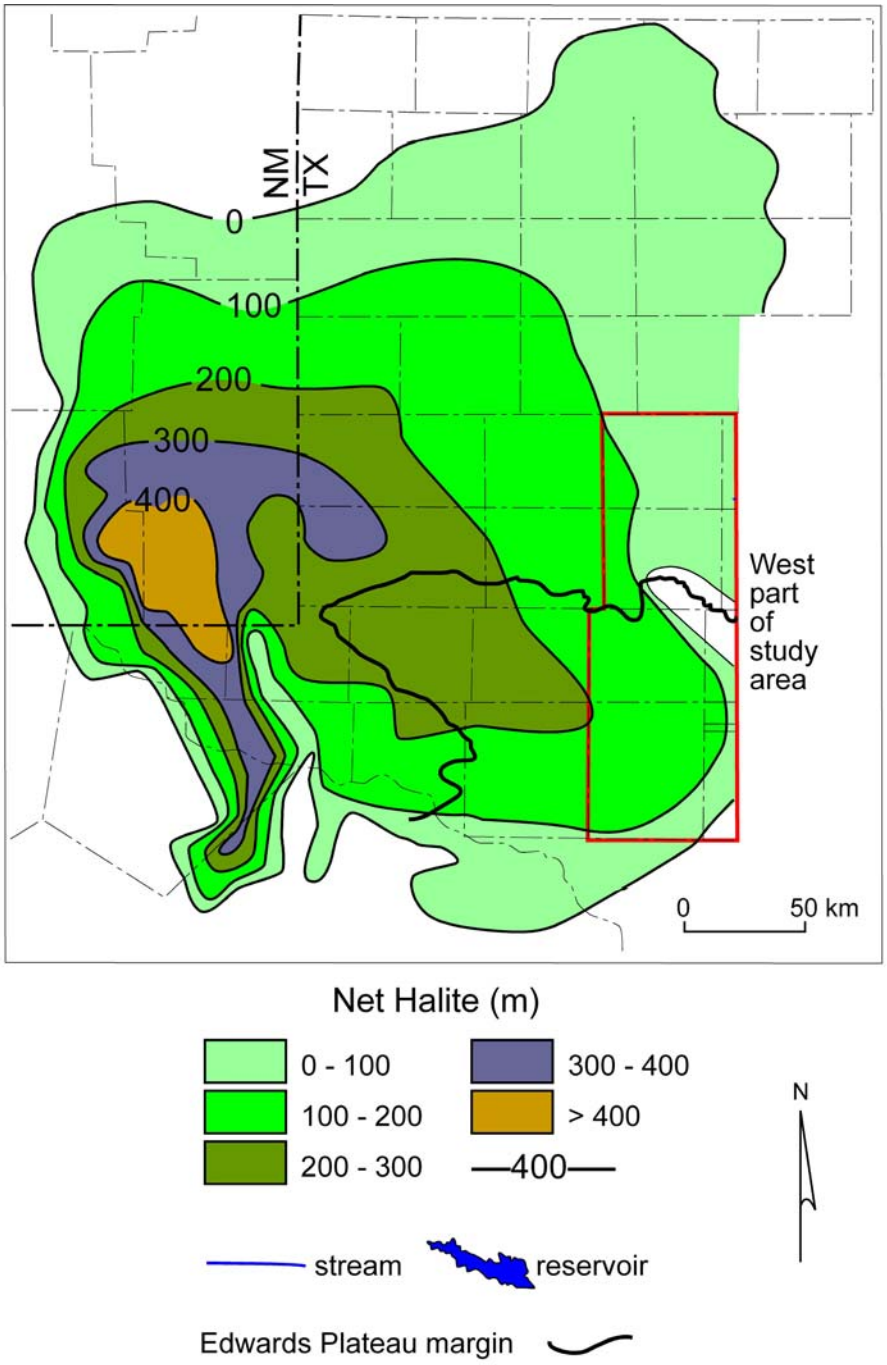

Figure 3.7. Net halite map for Salado Formation for most of extent in Texas and New Mexico. Portion of map within study area is outlined in red. Dissolved Salado halite is significant source of salinity to shallow groundwater and surface water. Modified from Lowenstein (1988) and Gustavson and others (1980).

Trinity Group (Fig. 3.5) is the most proximal to the Colorado River basin in the area and most Plateau groundwater in the area is produced from that unit (TWDB, 2009).

Dockum Aquifer

The Dockum Group consists of northwest-dipping continental micaceous, quartz-dominated siliciclastics of Late Triassic-age that were deposited in a closed, intra-continental fluvial-lacustrine basin (McGowen and others, 1979). The Dockum Group covers an area of about 96,000 sq. mi. (249,000 sq. km.) over four states (Bradley and Kalaswad, 2004) and covers all or parts of 46 counties in Texas (Ashworth and Hopkins, 1995). The prevailing stratigraphic framework of the Dockum Group recognizes five Formations including, from bottom to top, Santa Rosa, Tecovas, Trujillo, Cooper Canyon, and Redonna (Lehman and Chatterjee, 2005). The primary water-bearing zone in the Group is the Santa Rosa Formation (Dockum aquifer) which comprises the lower part of the interval and consists of up to 700 feet (213 m) of sand and conglomerate interbedded with layers of silt and shale (Ashworth and Hopkins, 1995). Some water is produced locally from sandy intervals above the Santa Rosa Formation, most probably from sand-prone parts of the Trujillo Formation.

The Dockum Group is subjacent to the Antlers sandstone aquifer (Plateau system) over a large area (Walker, 1979; Barker and Ardis, 1992, 1996) and is exposed in all or parts of at least seven counties in the study area (Brown and others, 1972; Eifler and others, 1994) (Fig. 3.4). In the subsurface the Santa Rosa Formation is hydraulically confined generally by mudrock in the superjacent Tecovas Formation.

Permian Aquifer System

The Permian section in the study area comprises northwest-dipping carbonate, evaporite (anhydrite, gypsum, and halite) and siliciclastic strata deposited during Lower through Upper Permian time (Wolfcampian, Leonardian, Guadalupian, and Ochoan series). Sediments accumulated in an extensive shallow platform setting that produced widespread lateral lithologic uniformity, especially in Leonardian through Ochoan Permian strata. Environmental conditions during Permian deposition became increasingly restricted through time in that marine circulation was reduced. Thus, carbonate rocks are much more common in the older than in younger intervals. Evaporites (anhydrite, gypsum, and halite) are more common in the younger Permian rocks. Near the surface much of the halite has been dissolved, especially near the large streams. However, halite, as well as gypsum still remain in abundance and greatly affect groundwater quality. The most permeable facies are the sandstones and carbonates.

The TWDB specifies 35 Permian intervals in the study area as aquifers, several of which are composites of units that are differentiated in other parts of the area. None are sufficiently large or prolific to be classified presently as either major or minor aquifers in the TWDB classification system. However, they are differentiated in the well-information database, a feature that allows consideration of aquifer-specific water qualities that form an element of this study.

Halite-Dissolution Zone

The halite-dominated Salado Formation (Ochoan) has been mapped from subsurface data to extend over much of the Permian Basin including parts of the Upper Colorado River basin (Fig. 3.7) (Gustavson and others, 1980; Lowenstein, 1988). Dissolution of Salado halite is widespread in the Permian basin (e.g., Gustavson and others, 1980; Johnson, 1981). Dissolution of Salado halite occurs in the presence of halite-undersaturated meteoric groundwater mainly at the top and along the lateral margins of halite strata, leaving less soluble gypsum as residue and contorted beds, and causing subsidence in overlying strata (e.g., Johnson, 1981; Gustavson and Finley, 1985; Nance, 1988). Dissolution products are transported in groundwater, often to be detected in surface water. Streams that traverse halite-dissolution zones are noted for their salt loads in the areas of ongoing dissolution (Gustavson and Finley, 1985). There appears to be a reciprocating effect whereby streams that provide halite-dissolving water are enlarged and maintained in their locations in response to subsidence produced by removal of underlying halite (Gustavson and Finley, 1985).

In the study area Salado Formation halite feathers out in the subsurface down dip of surface exposures of Permian strata and probably does not extend further east than central Mitchell and Scurry Counties, based on extrapolation of the mapped halite subsurface extent and the likely location beneath superjacent Dockum strata of the contact between Ochoan and Guadalupian strata (Fig. 3.4).

It is reasonable to infer that halite dissolution is active in the study area based on its shallow burial depth and absence of halite in outcrops that contain sulfate evaporites

normally associated with halite. Subsurface data indicate that Permian evaporite deposition was largely controlled by distance from marine-water sources and that halite facies extended further shelfward than did associated sulfate facies that generally are present at the base of sulfate-halite facies successions (e.g., Presley and McGillis, 1982). The present outcrops of Permian strata in the area are in a more paleo-shelfward position than are the subsurface occurrences where halite is present. Therefore, presence of thin sulfate beds in Permian outcrops within the study area strongly suggests that halite was formerly present but has been subsequently dissolved.

Deep-Brine Reservoirs

The study area is located in the midst of numerous oil fields developed in mainly Pennsylvanian and Permian carbonate and siliciclastic rocks of the Permian Basin Scurry Reef Trend (Kelly-Snyder, Westbrook, and Iatan-Howard field area) and Eastern Shelf (Fig. 3.8). Associated with these reservoirs are brines where [TDS] ranges up to 371,725 mg/L (Fig. 3.9A, A3.3). In addition to hydrocarbons, considerable volumes of brine also have been produced. There is evidence that deep- reservoir brines compose a significant fraction of groundwater and surface water in the area. Although Texas had regulations as early as 1919 regarding protection of fresh water from hydrocarbon operations, only after 1969 was it disallowed under Rule 8 to dispose of produced brines in unlined earthen pits (RRC, 2009). Previously, pits were often abandoned, and subject to meteoric leaching, thereby providing brine-contaminated recharge to the shallow subsurface. RRC files document occasional disregard of the Rule

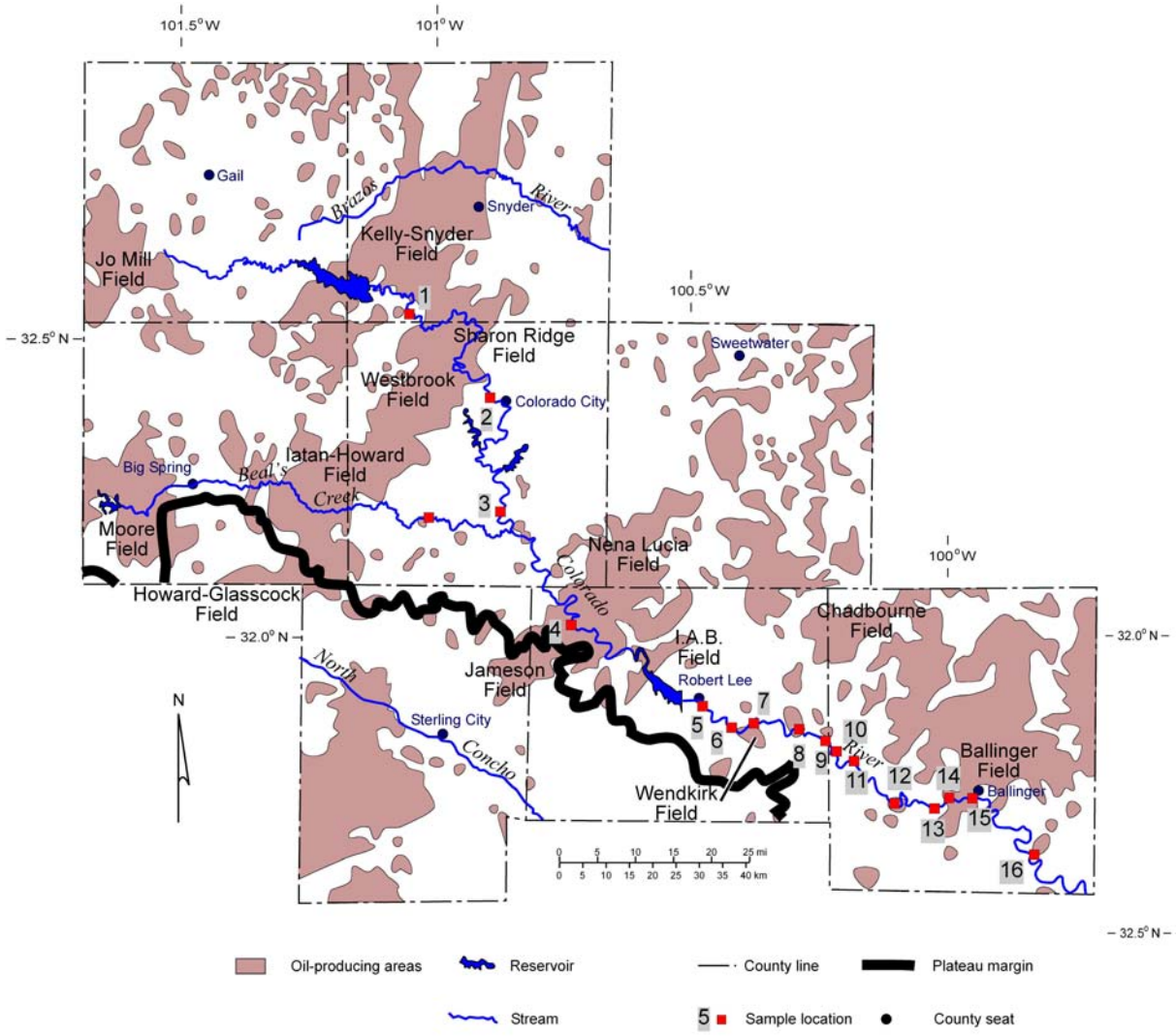

Figure 3.8. Distribution of oil-producing areas. Also shown are surface water locations where samples were collected for this project. Oilfield operations are a potential source of salinity to groundwater and surface water in the area. Relation of Wendkirk field (south-central part of area) to surface- and groundwater salinity is discussed in text.

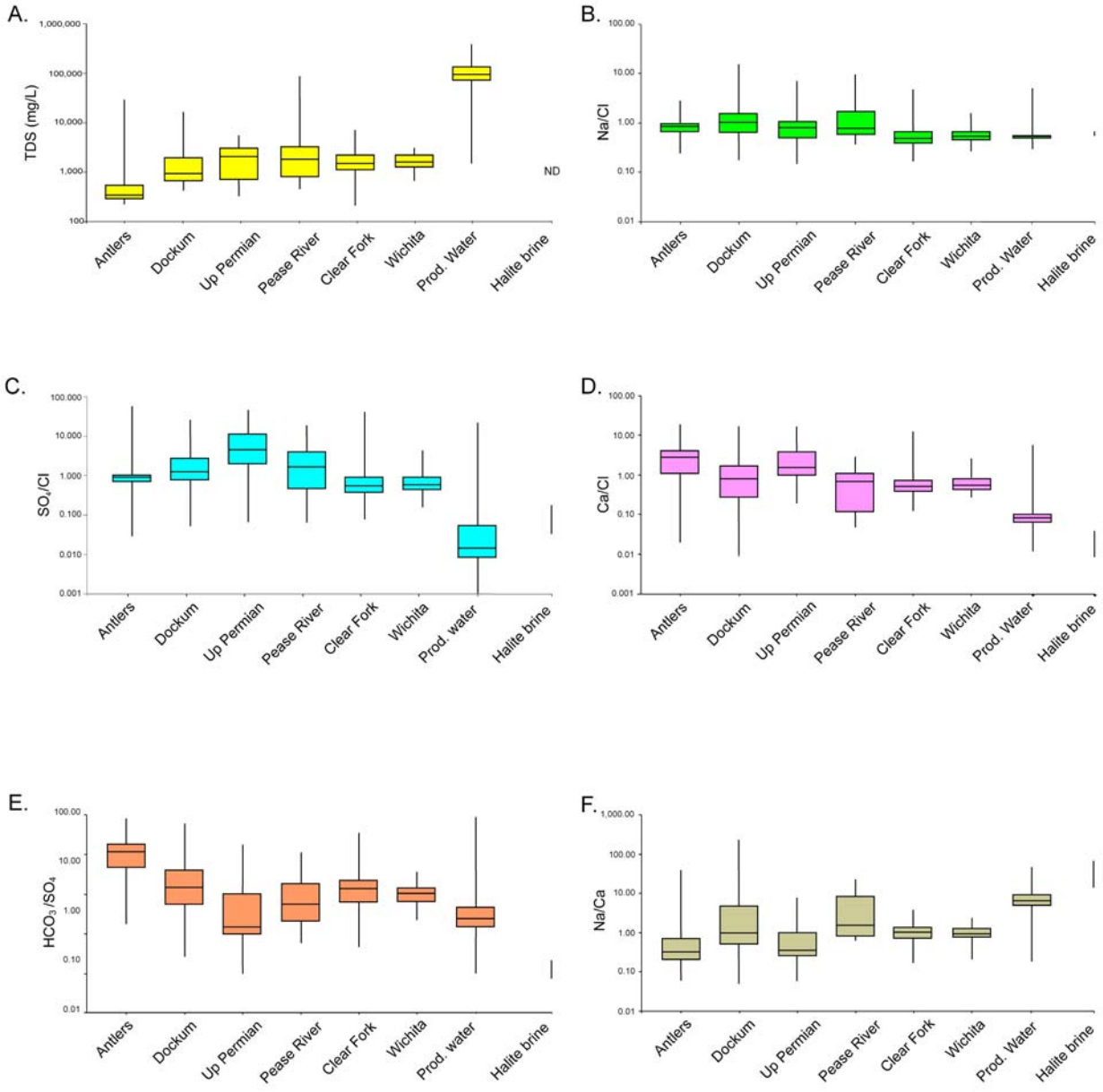

Figure 3.9. Box plots showing groundwater chemical parameters for aquifers most likely to contribute base flow to the Upper Colorado River: A) [TDS], B) Na/Cl, C) SO_4/Cl, D) Ca/Cl, E) HCO_3/SO_4, and F) Na/Ca. Plots show total range of values, interquartile range, and median values. Deep-brine aquifers are represented by produced waters on diagrams. Only range of halite-dissolution waters is represented due to limited data.

8 no-pit regulation, as well as of other regulatory guidelines that govern disposal of drilling and completion fluids (Nance and Dutton, 2002; Nance, 2003). There is also potential for leakage into aquifers from old and corroded casing pipe, poorly plugged and abandoned wells, or from brine injection wells (Reed, 1961; Rawson, 1982). Refining operations in the region have also contributed contaminants to groundwater and Upper Colorado River sediment in Mitchell County (Fig. 3.1) (TCEQ, 2009). Other studies have suggested the possibility that Dockum aquifer water with elevated dissolved solids concentrations in the oilfield area of Scurry County reflect a fraction of produced brine (Fig. 3.1) (e.g., Smyth and others, 2008).

There is also evidence from pressure data from hydrocarbon reservoirs and deep-brine reservoirs that potential exists for upward migration of brines, even to the land surface in some places (McNeal, 1965). The evidence is in the form of potentiometric surface maps, the data for which are fresh-water-equivalent hydraulic heads that have been calculated from down-hole pressure data. There were multiple practical issues involved in selecting data of adequate quality for such maps. Nonetheless, maps prepared for several stratigraphic intervals within the Pennsylvanian and Permian systems (McNeal, 1965) consistently indicate a potential field with decreasing head values toward the east in the Upper Colorado River study area (Fig. 3.10). Comparison of land surface elevations with the potentiometric surface map prepared for Wolfcampian reservoirs show that Wolfcampian hydraulic heads exceed land surface elevations in several areas within the Upper Colorado River drainage basin (Fig. 3.10). It follows that there is

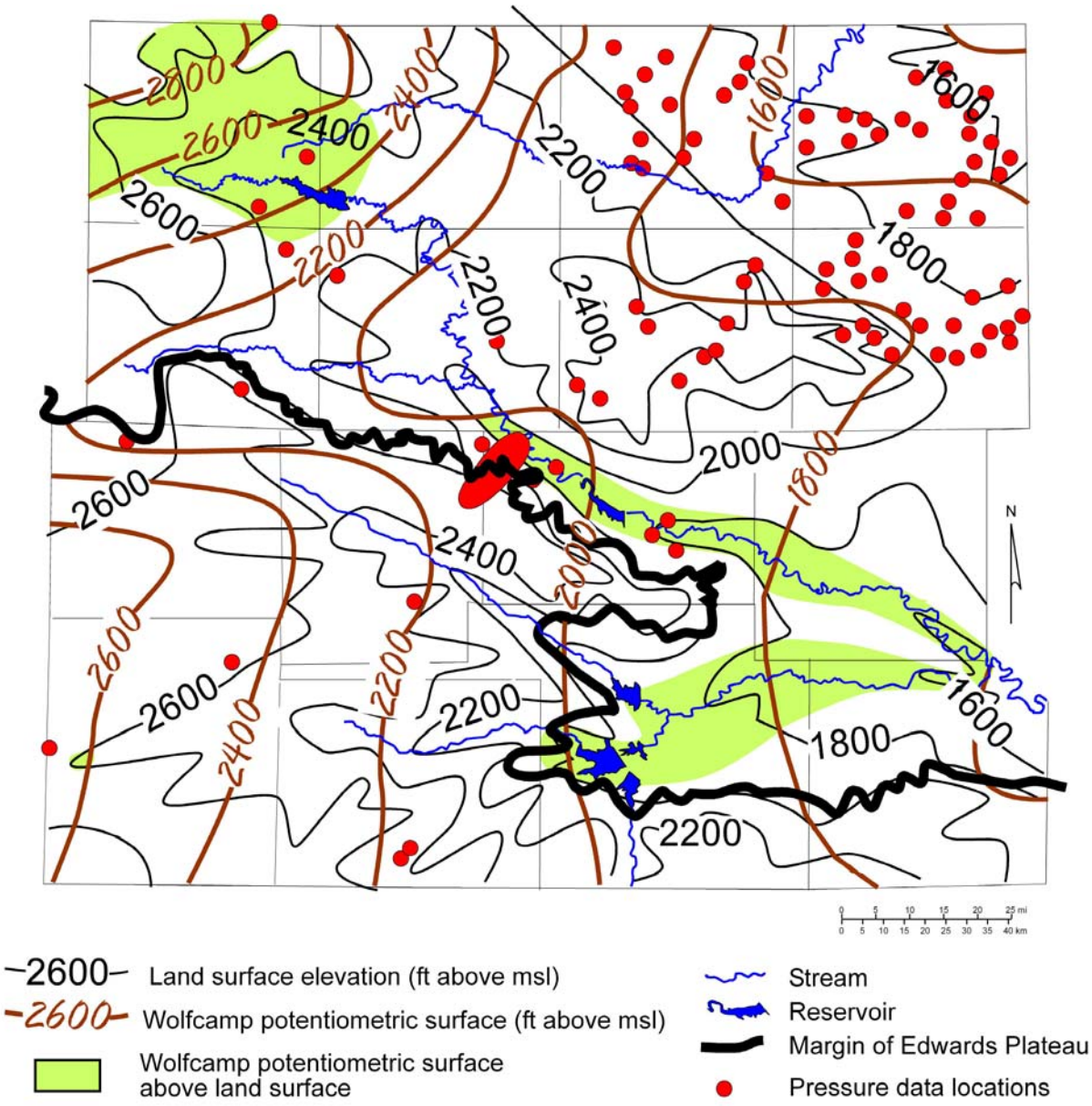

Figure 3.10. Simplified topographic map of study area showing potentiometric surface of ground-water in Wolfcamp Formation, based on fresh-water-equivalent hydraulic heads calculated from downhole pressure data. Modified from McNeal (1965). Data control points provided by the author are field locations. Also shown are locations where calculated heads exceed land surfaceelevations. Potentiometric head distributions suggest potential overall eastward flow of Wolfcamp brines and potential for upward flow where sub-vertical flow avenues (e.g., fractures and well bores) are available.

potential for upward movement of brines not only into the immediate area of the river but also into the shallow aquifers.

Previous Investigations

There have been several investigations of factors affecting relatively poor surface- and groundwater quality within the Upper Colorado basin (Reed, 1961; Mount and others, 1967; Leifeste and Lansford, 1968; Richter and Kreitler, 1987; and Richter and others,1990. The most recent include Slade and Buszka (1994), Paine and others (1999), Paine and Collins (2004), Paine and others (2006), and Nance (2006).

Regional geology of the Dockum has been discussed by Cummins (1891), Drake (1891), Gould (1907), Hoots (1926), Darton (1928), Adams (1929), Adkins (1932), Page and Adams (1940), McGowen and others (1979), Johns and Granata (1987), Johns (1989), and Lehman and Chatterjee (2005). Hydrochemical aspects of the Dockum aquifer have been discussed by Mount and others (1967), Dutton and Simpkins (1986), and Bradley and Kalaswad (2004).

Permian rocks in the Permian Basin have been addressed in the literature for over a century. Shumard (1858) performed one of the earliest reconnaissances. King's thorough investigations in the first half of the 20th Century (e.g., 1942) are still referenced extensively and without abundant correction. Cartwright (1930) published the first cross section across the Permian Basin into the study area that recognized the basic stratigraphic framework still in use today. The characteristics of Permian rocks in the study area vicinity and their regional stratigraphic equivalencies have been discussed by

Beede (1918), Beede and Bentley (1918), and Mear (1963). Little has been discussed concerning groundwater in Permian aquifers in the study area, aside from reporting of analyses from several wells completed in Permian aquifers along the Colorado River (Slade and Buszka, 1994). Analyses and discussion of the hydrochemistry of Permian aquifers within the most downstream parts of the study area are found in Richter and others (1990). Brief discussion of several Leonardian Series aquifers in the study area is found in Mount and others (1967).

Investigations and discussions of Plateau system regional hydrogeology and hydrochemistry can be found in Walker (1979), Hopkins (1995), Barker and Ardis (1992, 1996), and Bush and others (1994). Regional flow and groundwater availability for the Plateau have been modeled by Kuniansky and Holligan (1994) and Anaya and Jones (2008), respectively.

Relation of Study to Other Papers in This Dissertation

The other papers in this volume are concerned primarily with the Cretaceous-age Plateau aquifer system. One of the hypotheses advanced in those papers is that hydrochemistry of the Plateau system is affected by influx of waters derived from the Plateau system subcrop of Triassic and Permian rock. However, very little information is available for water quality of the Triassic and Permian sections beneath the Edwards Plateau because well completions are largely restricted to the Plateau system. Where the Dockum aquifer is contacted in some areas beneath the Plateau, wells are typically completed in both the Dockum and Antlers sandstone. Thus, these groundwaters are

comingled (Walker, 1979), and aquifer-specific hydrochemical qualities are obscured. Although the primary objective of this paper is to document groundwater-surface water interactions away from the Plateau, the study area comprises the eastward extension of the Plateau system subcrop and offers an opportunity to observe the geology and hydrochemistry of aquifers that are probably similar to those beneath the Plateau.

METHODS

The writer's samples were filtered through a 0.45μm syringe filter and analyzed by the Kansas Geological Survey (KGS). There were two plastic bottles for each sample. A filled, 500 mL bottle contained filtered water without preservative, and a 250 mL bottle contained 200 mL of filtered water preserved with 2 mL of 2N HCl.

Laboratory alkalinity (bicarbonate) and pH were determined using an automated titrimeter. Colorimetric methods on automated segmented-flow spectrophotometers were used to measure concentrations of SO_4^{2-}, Cl^-, NO_3^-, and Br^-. Preliminary sulfate measurements were made with a Hach test kit to determine sample dilutions for the optimum concentration range for the automated colorimetric method. The $[SO_4^{2-}]$ and specific conductance were used to determine the dilution for the optimum concentration range for chloride determination. The sample dilutions based on chloride and sulfate were used for optimization of bromide determination. The bicarbonate and sulfate concentrations were used to estimate the ranges in calcium and sodium contents for the optimum range for determination of cations, silica, and boron on an inductively coupled plasma spectrometer. Inorganic iodine and iodate concentrations were determined using

colorimetric methods on an automated segmented-flow spectrophotometer and used in the correction of apparent bromide to true values. Dissolved solids (TDS) concentrations were calculated from the sum of concentrations of Si, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Sr^{2+}, CO_3^{2-}, HCO_3^{-} (multiplied by 0.4917), SO_4^{2-}, Cl^{-}, NO_3^{-}, Br^{-}, and B. The factor of 0.4917 times the HCO_3^{-} concentration was used to better approximate TDS values that would be obtained by evaporating a sample to dryness (Hem, 1985). The charge balance error for the samples range from -1.3% to <2.1%. The KGS participates in the standard reference water program of the U.S. Geological Survey.

Geographic mapping was initially performed in ESRI ArcGIS and manually finalized with graphics software.

DATA

Data for this study included over 850 of the most recent (TWDB, 2008) charge-balanced (+/- 5%) hydrochemical analyses performed on groundwater samples collected from more than 850 water wells reported to have been completed in the Plateau aquifer system, Dockum aquifer, and Permian aquifers in the study area (Fig. 3.11). Hydraulic head data acquired since 1959 for 6,671 wells were used to prepare a potentiometric surface map (Fig. 3.2). These hydrochemical and water-level data sets are maintained the Texas Water Development Board (TWDB, 2009). Hydrochemical data for produce water from 1,485 hydrocarbon wells were provided by the United States Geological Survey (2006) and, for 3 wells, by Slade and Buszka (1994). Analyses for B and Br^{-} w provided for 32 wells completed in Dockum and Permian aquifers in the study area by

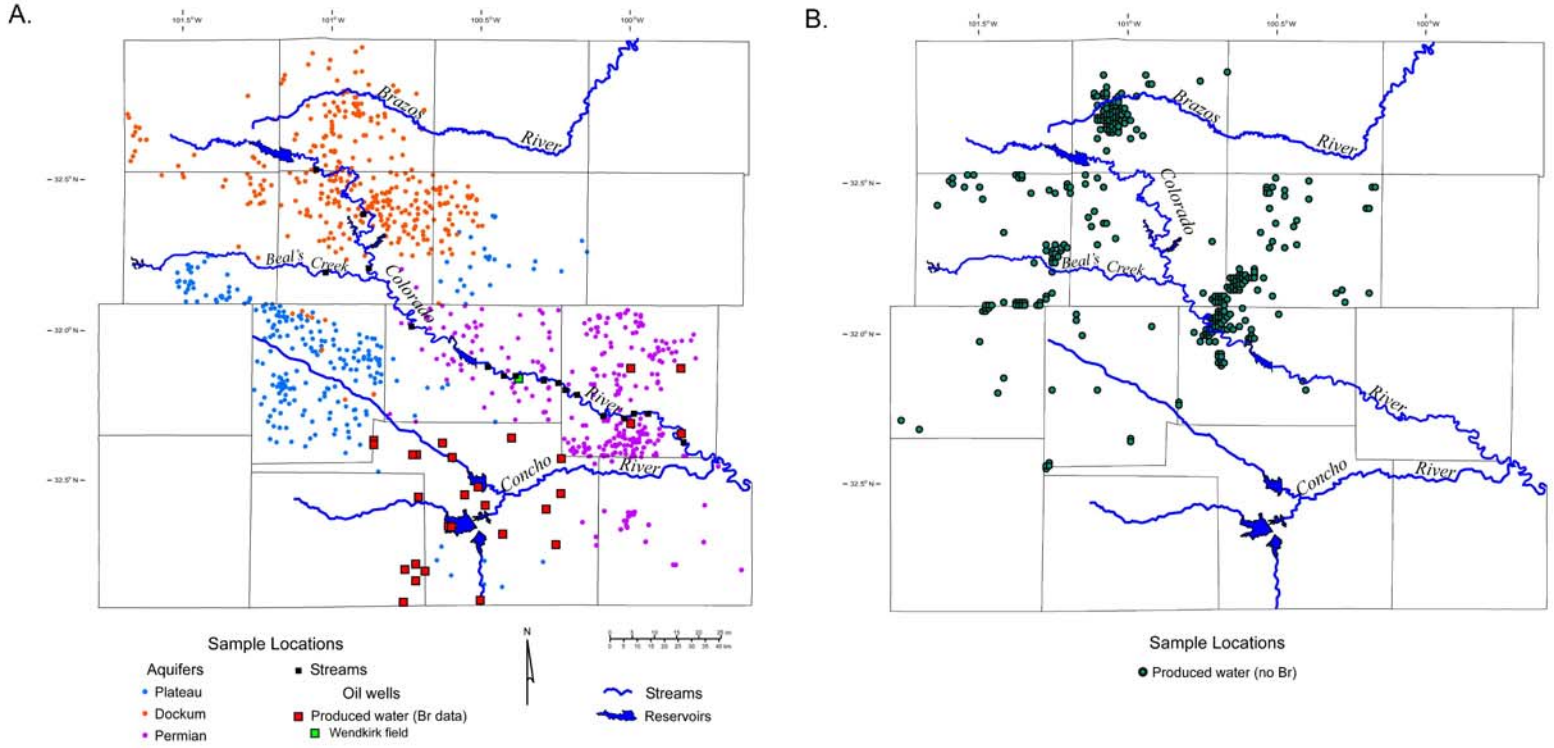

Figure 3.11. Base maps of study area showing locations of hydrochemical data for A) shallow-aquifer groundwater, produced water with Br data, and surface water; and B) produced water without Br^- data.

Slade and Buszka (1994). Additional surface-water data for 18 locations and one hydrocarbon well were acquired by the writer during a sampling campaign conducted during 2005.

RESULTS

This paper uses brackets to indicate ionic concentration (e.g., $[SO_4^{2-}]$), whereas brackets and ionic charge are eliminated for ratios (e.g., SO_4/Cl). [TDS] and anion analyses are summarized here because TDS and anion concentrations are the primary concerns for water quality in the study area. Boron (B), an exception because it does not carry an ionic charge, is also included because of its importance in this report for baseflow-source interpretation. Cation concentrations, required for calculation of certain ratios (e.g., Na/Ca) that are used in this report, are found in A3.2.

Stream Quality

Upper Colorado River [TDS] ranges from 1,667 to 8,430 mg/L (median 2,870 mg/L); $[Cl^-]$ ranges from 373 to 3,950 mg/L (median 974 mg/L); $[SO_4^{2-}]$ ranges from 566 to 1,500 mg/L (median 1,030 mg/L); $[HCO_3^-]$ ranges from 204 to 344 mg/L (median 239 mg/L);$[Br^-]$ ranges from 1.1 to 14.3 mg/L (median 2.3 mg/L); and [B] ranges from 0.38 to 0.92 mg/L (median 0.51 mg/L).

Groundwater Quality

Hydrochemical anion analyses from the several aquifer systems in the study area are summarized below and are tabulated in A3.1. Constituent ratios that are used in this report are summarized in Figure 3.9.

Halite-dissolution brine [Cl^-] ranges from 35,100 to 170,400 mg/L (median 53,900 mg/L); [SO_4^{2-}] ranges from 4,725 to 5,900 mg/L (median 5,655 mg/L); [HCO_3^-] ranges from 39 to 73 mg/L (median 54 mg/L); [Br] ranges from 6.2 to 58 mg/L (median 21.7 mg/L). [TDS] values were not available; however, the sum of average major ion values alone equaled nearly 151,000 mg/L.

Deep-reservoir brine (produced water) [TDS] ranges from 10,075 to 372, mg/L (median 97,800 mg/L); [Cl^-] ranges from 5,190 to 230,670 mg/L (median 58,346 mg/L); [SO_4^{2-}] ranges from 2 to 7,360 mg/L (median 932 mg/L); [HCO_3^-] ranges from 1 to 2,950 mg/L (median 216 mg/L); [Br] ranges from 9.9 to 480 mg/L (median 78 mg/L); and [B] ranges from 3 to 7.5 mg/L (median 6.3 mg/L).

Antlers (Plateau system) [TDS] ranges from 210 to 10,256 mg/L (median 311 mg/L); [Cl^-] ranges from 7 to 16,330 mg/L (median 23 mg/L); [SO_4^{2-}] ranges from 4 to 1,500 mg/L (median 24 mg/L); [HCO_3^-] ranges from 82 to 483 mg/L (median 262 mg/L); [Br] ranges from 0.03 to 3.87 mg/L (median 0.14 mg/L); and [B] ranges from 0.05 to 0.5 mg/L (median 0.13 mg/L).

Dockum aquifer [TDS] ranges from 185 to 17,000 mg/L (median 830 mg/L); [Cl^-] ranges from 7 to 15,500 mg/L (median 101 mg/L); [SO_4^{2-}] ranges from 0 to 4,700 mg/L (median 193 mg/L); [HCO_3^-] ranges from 7 to 756 mg/L (median 297 mg/L); [Br] ranges

from 0.08 to 37 mg/L (median 0.53 mg/L); and [B] ranges from 0.04 to 2.06 mg/L (median 0.36 mg/L).

Upper Permian aquifer [TDS] ranges from 329 to 5,224 mg/L (median 2,417 mg/L); [Cl^-] ranges from 120 to 1,600 mg/L (median 106 mg/L); [SO_4^{2-}] ranges from 23 to 2,450 mg/L (median 1,180 mg/L); [HCO_3^-] ranges from 24 to 406 mg/L (median 222 mg/L); [Br] ranges from 0.9 to 8.0 mg/L (median 1.7 mg/L); and [B] ranges from 0.21 to 0.96 mg/L (median 0.45 mg/L).

Pease River aquifer [TDS] ranges from 455 to 85,400 mg/L (median 2,059 mg/L); [Cl^-] ranges from 37 to 49,400 mg/L (median 223 mg/L); [SO_4^{2-}] ranges from 23 to 4,100 mg/L (median 830 mg/L); [HCO_3^-] ranges from 206 to 504 mg/L (median 364 mg/L); [Br] ranges from 1.5 to 7.3 mg/L (median 3.45 mg/L); and [B] ranges from 0.15 to 5.8 mg/L (median 1.4 mg/L).

Leonardian Series (Clear Fork, Wichita) aquifers [TDS] ranges from 204 to 7,200 mg/L (median 1,531 mg/L); [Cl^-] ranges from 5 to 3,100 mg/L (median 384 mg/L); [SO_4^{2-}] ranges from 6 to 2,500 mg/L (median 234 mg/L); [HCO_3^-] ranges from 51 to 540 mg/L (median 272 mg/L);[Br] ranges from 1.9 to 7.9 mg/L (median 4.9 mg/L); and [B] ranges from 0.63 to 1.1 mg/L (median 0.84 mg/L) (A3.1)

DISCUSSION

Stream Hydrochemical Evolution

In order to understand the impact of groundwater quality on stream chemistry

along it flow path it is necessary to document: 1) geographical variations in stream chemistry, 2) qualities of the groundwater that discharges to the stream, and 3) hydrodynamic influences on base flow quality to the stream along its flow path. Addressing item 1) is a description of geographic surface water variations based on chemical analyses Addressing item 2) requires a statistical approach that recognizes the central tendencies of aquifer-specific groundwater qualities because all the useful data types are not everywhere available for all the aquifers. Addressing item 3) requires interpreting hydrodynamic probabilities based on reference to potentiometric surfaces. Integrating conclusions drawn from addressing items 2) and 3) to interpret the probably influence on surface water by groundwater quality involves documenting proximity of surface water sample locations to specific aquifer systems, and likelihood that certain aquifer systems are contacted by groundwater flow prior to discharging to the river.

Dissolved Solids and Chloride Trends in Stream Water

The dissolved solid load and chloride concentration generally decrease downstream in the Upper Colorado River. Predictably, increases and decreases in [TDS] show corresponding similar trends in [Cl^-] concentration (Fig. 3.12A). Values for both parameters show relatively higher rates of decline over distance in the upstream segments than in more downstream segments. In the most upstream sample [TDS] exceeds 8,000 mg/L (Fig. 3.12A). [Cl^-] at the same location was 3,950 mg/L. This sample was collected

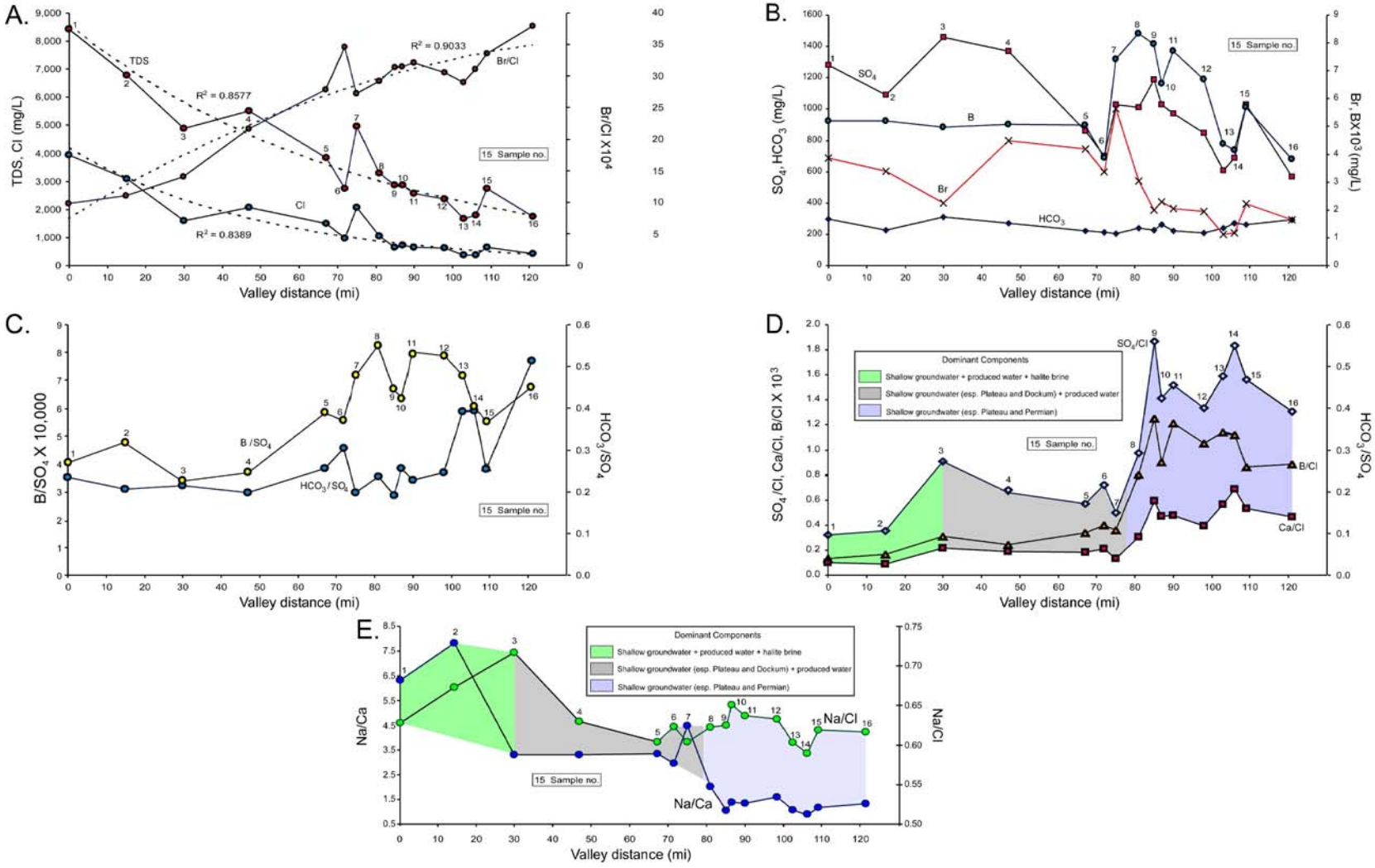

Figure 3.12.Graphs showing for surface water samples A) [TDS], [Cl^-], and Br/Cl; B) [SO_4^{2-}], [B], [Br^-], and [HCO_3^-]; C) B/SO_4 and HCO_3/SO_4, D) SO_4/Cl, B/Cl, and Ca/Cl; and E) Na/Cl and Na/Ca as a function of shortest distance between sample locations (i.e., valley distance). Systematic association of constituent rations depicted in D) and E) are suggested to indicate that the river consists of 3 distinct hydrochemically characterized segments, each of which reflects relative dominance of base flow from specific shallow aquifers, brine sources, or combinations thereof.

in the immediate vicinity of the Sharon Ridge oil field (Fig. 3.8). Dissolved solids concentration at the most downstream location is 1,739 mg/L (433 mg/L Cl^-). The decreasing [TDS] along flow closely is closely approximated by the regression curve in Figure 3.12A. The downstream trend of decreasing [TDS] and [Cl^-] values shows local increases (Fig. 3.12A). These trend reversals occur at location 4, within the boundaries of Jameson oil field and a short distance downstream of where Beal's Creek intersects the river; at location 7, near the Wendkirk oil field; and at location 15, within the city limits of Ballinger near Rowena oil field (Fig. 3.8).

Salinity in the river varies loosely with flow rate (Fig. 3.3B). Salinity usually decreases with increased flow, but the reverse occasionally occurs. The non-ideal congruence between flow rate and salinity can be seen in both monthly averages (Figs. 3.3B, 3.3C) and weekly averages (USGS, 2009). The response of salinity to flow rate is complicated by capture of runoff to reservoirs and by operational variations in dam releases conducted at the several reservoirs constructed on the river and tributaries upstream of the USGS monitoring station at Ballinger, TX (Fig. 3.4). The only regular flow and salinity (based on specific electrical conductivity) measurements on the river are conducted at Ballinger. Base flow calculations from incremental measurements of stream discharge along the stream course were not conducted during this study.

Major and Minor Ion Trends in Stream Water

Based on ion proportions calculable from stream-water analyses in A3.2, Na-Cl hydrochemical facies characterize the more upstream 8 samples collected for this study.

The more downstream 8 samples are mixed cation-anion facies with subequal proportions of Na^+, Ca^{2+}, SO_4^{2-}, and Cl^-.

The stream water values for concentrations of major ions, boron, and dissolved solids are shown in Figures 3.12A and 3.12B. As mentioned in the discussion of salinity, there is an overall downstream decrease in [Cl^-]. Except for Br/Cl, the other constituent concentrations and constituent ratios presented do not show the same relatively uniform incremental variations with distance as do [TDS] and [Cl^-]. [SO_4^{2-}] and [Br^-] generally are reduced sharply in more downstream reaches of the river, whereas [B] is elevated sharply in the same area. [HCO_3^-] shows very little variation between locations.

Certain stream ionic constituent ratios show downstream systematic variations (Fig. 3.12). Ratios of the major ions and B/Cl values show less uniform patterns and can be organized into 3 general groups based on ranges of values and geographic position along the river course. In the most upstream river segment (locations 1 and 2) values of Ca/Cl, SO_4/Cl, and B/Cl are within the lowest parts of their ranges. In the most downstream segment (locations 8 to 16) values of SO_4/Cl, B/Cl, and Ca/Cl are within the highest parts of their ranges. The data values from the middle segment of the river are transitional between the upstream and downstream datasets with intermediate values for Ca/Cl, B/Cl, and SO_4/Cl. Although trends for HCO_3/SO_4 and B/SO_4 do not strictly parallel the variations in the other constituent ratios and can't easily be organized into upstream, mid-stream, and downstream groups, the highest HCO_3/Cl and B/SO_4 values also occur within the sample set from locations 8 to 16. Of these, the distribution of elevated B/SO_4 values most closely parallels the trends of elevated SO_4/Cl, B/Cl, and Ca/Cl values.

Na/Ca values for stream water occur in three general groups that show systematic distribution along the river (Fig. 3.12E): 1) Na/Ca > 6.3 characterize the two most upstream samples; 2) Na/Ca of 3 to 4.5 characterizes samples from locations 3 to 7; and Na/Ca < 2.1 characterize samples from locations 8 to16. Similarly, Na/Cl values show variations that can be organized into the similar groups defined by location along the river. In the most upstream segment (locations 2 and 3) the Na/Cl values are the highest among all samples, ranging from approximately 0.63 to 0.67. In the most downstream segment (locations 8 to16) show the greatest overall difference between Na/Ca and Na/Cl values (except for location 3 at the transition between the upstream and middle segments) where Na/Ca ranges from approximately 0.86 to 2.0, while Na/Cl ranges from approximately 0.59 to 0.65. Like the values for Ca/Cl, B/Cl, and SO_4/Cl, Na/Ca and Na/Cl values from the middle segment of the river are overall transitional between the upstream and downstream value ranges. Further discussion of hydrochemical segmentation of the river follows below in the section on chemically distinguished river segments.

Groundwater Quality

Hydrochemical Distinctions for Aquifers

In the remaining sections aquifers composing the Plateau, Dockum, and Permian systems within which shallow water wells are completed for abstraction of groundwater generally useful for human consumption or agriculture are referred to as “shallow

aquifers" to distinguish them from brine reservoirs (halite-dissolution zone and deep-brine reservoirs), although the halite-dissolution zone occurs at shallow depths.

Each of the aquifers in the study area produces groundwater with statistically distinct combinations of chemical qualities (Fig. 3.9, A3.1). The distinctiveness of aquifer-specific hydrochemical qualities is due to predominance dominance in each formation of specific depositional and diagenetic facies, or possibly influence of industrial operations (e.g., oil field production) in some areas where a particular aquifer is the primary producer of water to wells from which samples were collected.

The hydrochemical distinctions are described by the central tendencies of constituent parameters as illustrated by the ranges of the interquartile distribution, or the 50% of samples with values that occur closest to the median value for a parameter. The interquartile ranges, total ranges, and median value for six hydrochemical parameters for six aquifers and for stratigraphically undifferentiated produced waters are shown in Figure 3.9. The parameters used are [TDS] and ratios of major ionic constituents (Ca^{2+}, Na^{+}, Cl^{-}, HCO_3^{-}, and SO_4^{2-}) that are calculable from most water analyses. There is overlap in the ranges for all parameters among all the aquifers, probably due to groundwater mixing, local similarities between separate aquifers in mineral composition and because all may have been contaminated locally by brine. Figure 3.9 shows that, although it is generally difficult to distinguish between groundwaters from individual Permian system aquifers, the differences in certain hydrochemical parameters help differentiate between groundwaters from deep-brine reservoirs, Permian system aquifers,

and Plateau system aquifers. The following discussion emphasizes comparisons of the hydrochemical interquartile ranges shown for the aquifers (Fig. 3.9).

Most of the aquifers are similar in median dissolved solids content except for siliciclastic-dominated Antlers water, which is distinctively lower than the others and for produced water that has much higher concentrations (Fig. 3.9A). The overall lower salinity of Antlers water reflects comparatively insoluble aquifer matrix, although some carbonate occurs as cement and, perhaps, in a few thin beds. It is shown that waters from shallow aquifers with salinities that are elevated significantly above their interquartile ranges have hydrochemical similarities with brines from the area. Although the siliciclastic-dominated Dockum aquifer is generally devoid of highly soluble minerals it appears to be significantly contaminated by saline water from other sources. Similar contamination is shown to explain the higher values in the ranges of all aquifers in the area.

Na/Cl median values are significantly greater for the Mesozoic aquifers than for the Permian and deep-brine reservoirs (Fig. 3.9B). Useful references for these data are a pure Na/Cl brine value of 0.65, and an average seawater value of 0.56 (mg/L units). Given that Na-bearing minerals other than halite are not abundant in any of these rocks Na/Cl values of greater than 0.65 (Na/Cl of halite) may be attributed to varying degrees of cation exchange whereby Na^{+} is displaced by Ca^{2+} and Mg^{2+} from exchange sites on fine particles in aquifer matrices. The proposal for cation exchange in the shallow aquifers is supported by the relationship seen in their waters whereby Na/Cl values greater than unity (in equivalent units) generally also have $(Ca+Mg)/(HCO_3 + SO_4)$ values less than

unity (Fig. 3.13). Na/Cl greater than unity suggests an additional source for Na^+ other than halite dissolution. The value $(Ca+Mg)/(HCO_3 + SO_4)$ describes the balance between cations and anions produced by dissolution of calcium sulfate, calcite, and dolomite which are the dominant minerals (other than NaCl, possibly) in the aquifers. Values less than unity suggest that the divalent cations have been removed from solution. This is reasonable expectation for the clay-bearing Antlers, which receives meteoric recharge by Ca-enriched water discharging from overlying Edwards Plateau carbonates. The original source of sodium may have been sea water. The highest median value for the Dockum aquifer may reflect the abundance of clay in the system that facilitates ion exchange. The Dockum extends beneath the Plateau aquifer system and has access to the same Ca^{2+}- and Mg^{2+}-enriched recharge received by the Antlers. The very narrow ranges of Na/Cl values around a median value of 0.53 in the produced waters probably reflects their primary origin as evaporated sea water.

Elevated groundwater SO_4/Cl values (Fig. 3.9C) reflect the relative prominence of $CaSO_4$ in aquifer matrices or, in the case of deep-reservoir brines, lower SO_4/Cl values reflect the prominence of Cl^-. The overall higher values of SO_4/Cl in Peace River and Upper Permian aquifer groundwater reflect the increasing proportion over time of sulfate evaporite precipitation along the circulation-restricted margins of Permian seas (Fig. 3.5). Higher values in the Dockum compared to Antlers groundwater may reflect the direct contact of the Dockum with subjacent Permian gypsum-bearing rocks and a history of upward cross-formational groundwater flow. The plausibility of cross-formational flow

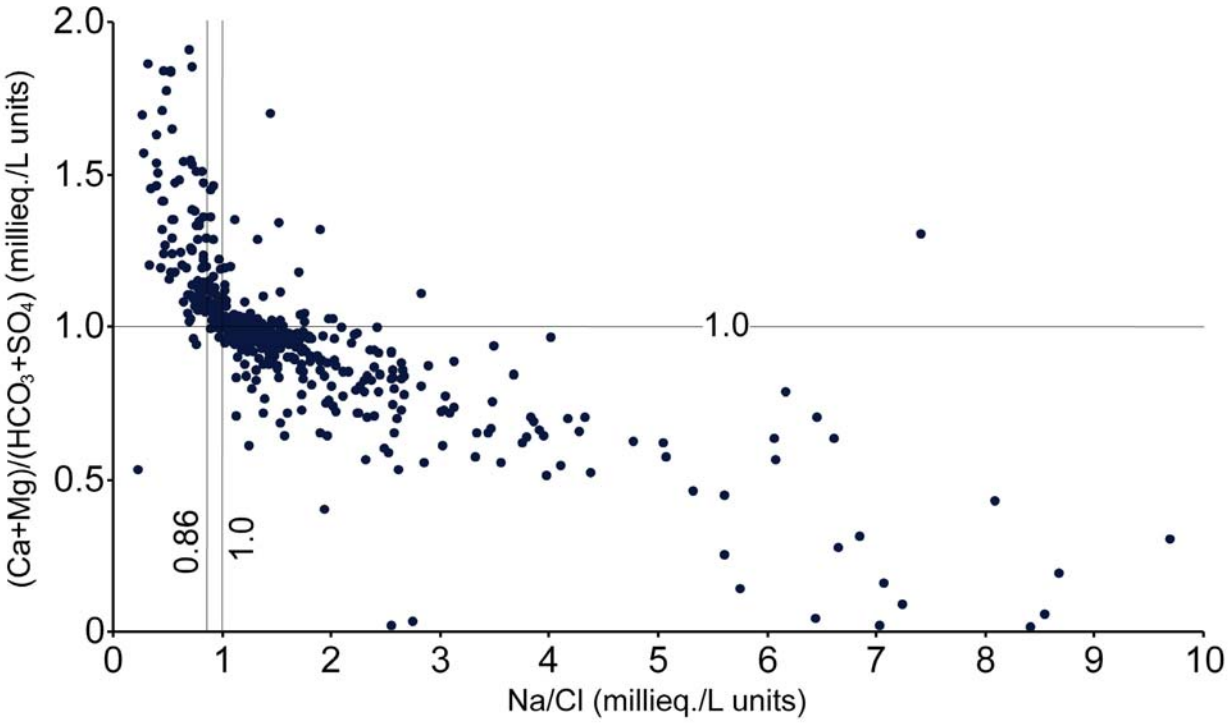

Figure 3.13. Relationship of charge balance between dissolution products of carbonate and calcium sulfate aquifer matrix and Na/Cl values. Na/Cl values (milliequivelents/L units) exceeding 1.0 suggest an excess of Na^+ greater than that anticipated for halite dissolution, whereas $(Ca+Mg)/(HCO_3+SO_4)$ values less than 1.0 suggest a deficit of divalent cations for carbonate and calcium sulfate dissolution. Other sources for Na^+ are insufficient to account for Na/Cl imbalance. Cation exchange processes are suggested where $[Na^+]$ excess corresponds to divalent cation deficit. For reference, ideal values of Na/Cl for halite dissolution (1.0) and mean seawater (0.86) are also shown.

from Permian aquifers through the Dockum into the Edwards aquifer, based on locally elevated [SO_4^{2-}], is discussed by Nance (this volume).

Ca/Cl values show considerable overlap in ranges for the shallow-aquifer groundwater and are not particularly distinct for any aquifer in the area. Elevated Ca/Cl values reflect the prominence in aquifer matrices of calcite, dolomite, calcium sulfate, or any combination thereof. These minerals are present in all the aquifers either as strata or cement. Elevated Ca/Cl can also reflect the influx of Ca-enriched recharge, which is probably part of the case with Antlers groundwater. The Antlers also contains some carbonate cement, however, that probably records re-precipitation of minerals dissolved from the overlying Edwards aquifer during Antlers recharge. Although less helpful in distinguishing the influence of any particular mineral in the hydrochemistry of a study-area aquifer than sulfate, for example, it distinguishes shallow aquifer groundwaters from deep-reservoir brine which exhibits depressed Ca/Cl values due to its greatly elevated [Cl^-].

HCO_3/SO_4 ranges for the Dockum and Permian groundwaters also show considerable overlap (Fig. 3.9E), although the greater medians in the Clear Fork and Wichita aquifers probably reflect a greater prominence of carbonates and its dissolution in those aquifers compared to younger Permian aquifers which have more evaporites and siliciclastics (Fig. 3.5). The distinctively elevated HCO_3/SO_4 values for Antlers water probably is owed to recharge through superjacent Edwards carbonates.

Na/Ca values do not strongly differentiate between the several shallow aquifers in the study area. On the other hand, study-area brines have higher Na/Ca values than

groundwaters from the shallow aquifers. Thus, it may be possible to interpret the presence of brines in their mixtures with groundwater from a shallow aquifer whose statistically most representative groundwater compositional ranges have significantly lower Na/Ca values than those observed in a given sample abstracted from that aquifer. This approach would appear especially valid if increases in Na/Ca accompanied elevated values in [TDS].

Evidence of Brine Content in Shallow Groundwater

Several lines of hydrochemical evidence suggest that groundwater in the study area contains either deep-reservoir brine, halite-dissolution brine, or both. This evidence is 1) local salinity elevation in aquifers that are generally much less saline, and 2) the relationship between salinity (TDS) and several constituent parameters that show overall systematic variation with salinity. Salinity, in terms of [TDS], varies from 185 mg/L to over 85,000 mg/L in the units investigated in this study. The values at the high end of the ranges (>10,000 mg/L) are well within the ranges of brines sampled from hydrocarbon wells in the region and suggest a large fraction of deep-reservoir brine.

Brine content in groundwater is also suggested by systematic increases in chloride percent and Na/Ca values with increasing [TDS] (Fig. 3.14). Therefore, the most likely source of elevated salinity in groundwater that shows a direct relationship between [TDS] and elevated Na/Ca is deep-reservoir or halite-dissolution brines. Sources for both brine-types are available. The study area is solidly within a major hydrocarbon producing province (Fig. 3.8). Contamination of groundwater and surface water in the region by

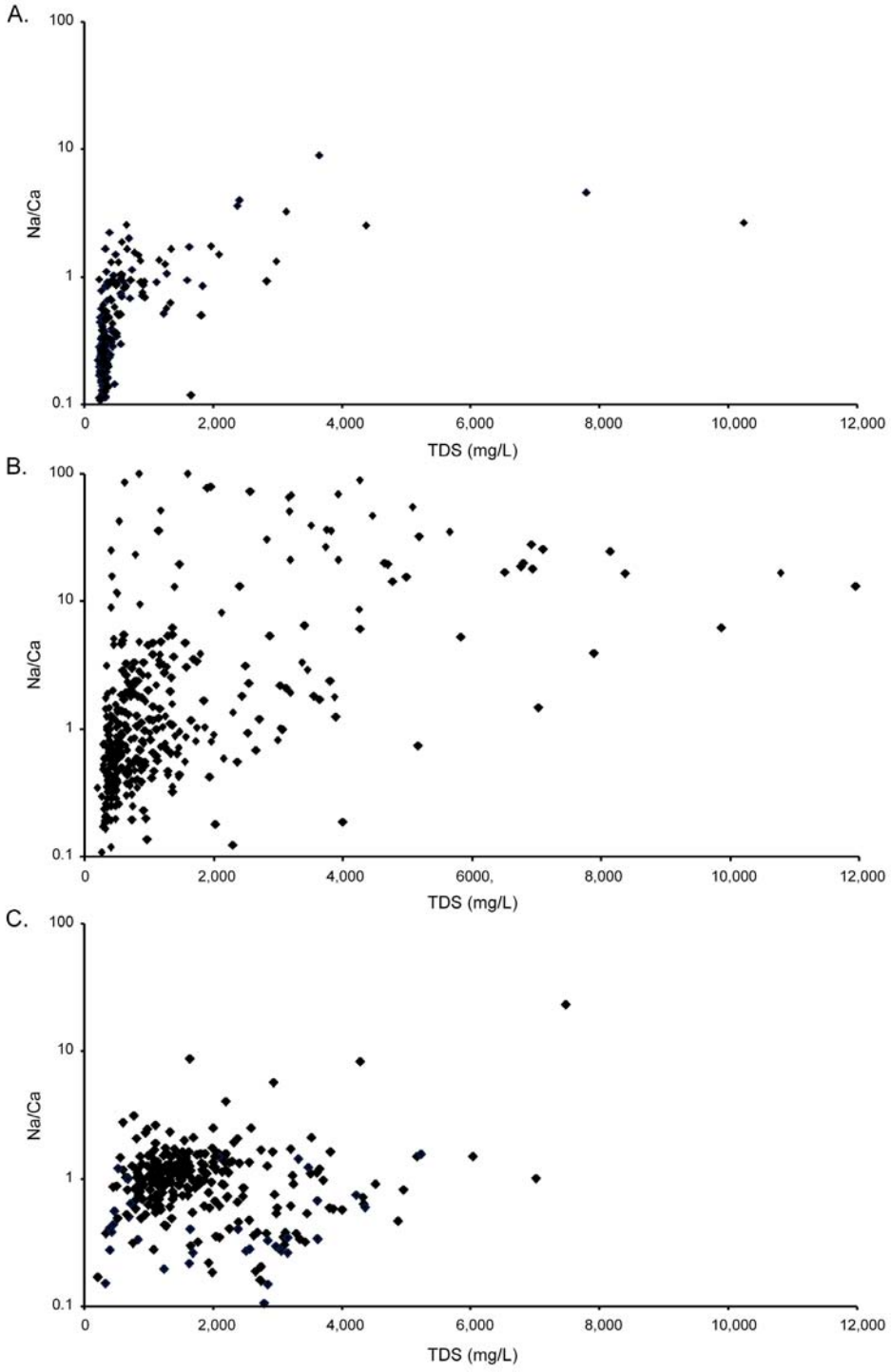

Figure 3.14. Relationship between Na/Ca and [TDS] in A) Plateau system, B) Dockum, and C) Permian system shallow aquifers. Increased Na/Ca values at increased [TDS] in groundwater suggest that salinity increases are largely controlled by contributions from halite-dissolution and deep-aquifer brines.

deep-reservoir- and produced water has been reported for decades (e.g., Reed. 1961; Richter and others, 1990). Permian-halite dissolution and migration of dissolution-brines through shallow aquifers to surface water is also well-documented along the perimeter of the Permian Basin (e.g., Gustavson and others, 1980; Johnson, 1981; Dutton, 1987).

Determining which of the two brine types are the most influential in salinization of a specific sample is facilitated by Br^- data. Lower values of Br/Cl suggest the significant influence of halite-dissolution brines (Braitsch, 1971), especially when in ranges near that or below those of deep-reservoir brines with Br/Cl values near the bottom of the ranges for produced waters (Fig. 3.15). Br/Cl ($\times 10^4$) values for the produced waters exceed 8.5, whereas halite-dissolution brine values are all less than 4.2. However, in a system where both brine types may be mixing, even Br/Cl values or other conservative-constituent criteria may not provide a definitive resolution as to which type is the more significant.

Evidence from the relationships between SO_4/Cl may address the brine-origin issue. Among the study area groundwaters low SO_4/Cl values appear to distinguish deep-reservoir brines more that any other parameter (Fig. 3.9), although the upper ranges of values overlaps with the other aquifers. Approximately 75% of produced water SO_4/Cl values are less than the lower ranges (approximately 0.051) for any of the other aquifers. The ranges of SO_4/Cl for the limited set of halite-dissolution brines is from 0.03 to 0.17 with 4 of the 6 halite-dissolution samples exceeding 0.08. In general, deep-reservoir brines appear to have lower SO_4/Cl than halite-dissolution brine. The cause of elevated SO_4/Cl in halite dissolution brine is the stratigraphic association of anhydrite with halite in Permian evaporite successions. For the Dockum aquifer SO4/Cl values tend to increase

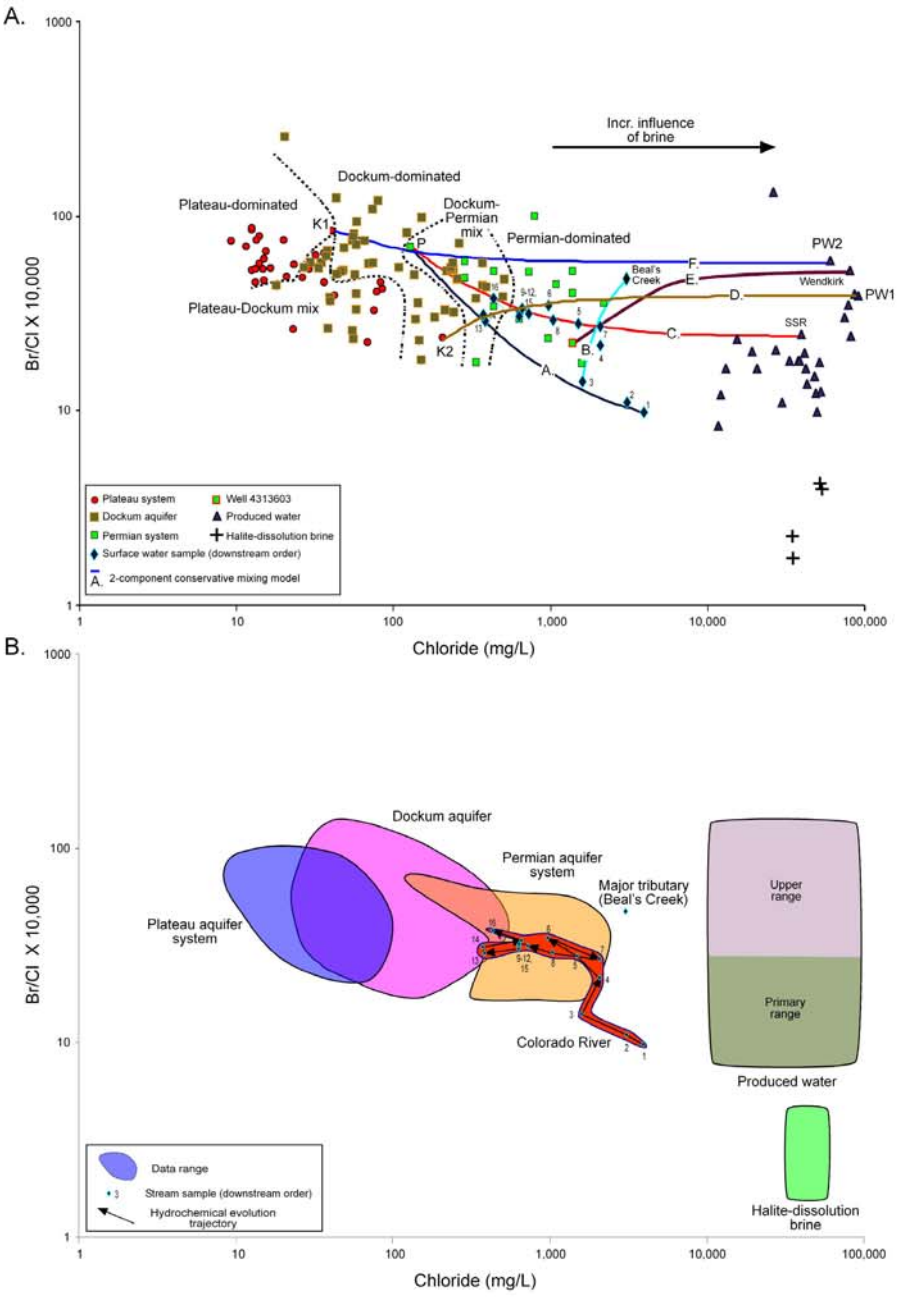

Figure 3.15. Graphs showing relationship between Br/Cl and [Cl^-] in groundwaters and surface waters in study area: individual data for shallow aquifers, halite-dissolution brines, produced water, and stream water (15A); and generalization of above depicting value ranges of groundwaters, trajectory of variations in surface water values, and mixing models with end-members (15B). Overall trajectory of surface water is toward decreased [Cl^-] and increased Br/Cl values interpreted to mark increasing influence of Plateau system groundwater. The sharp increase in Br/Cl to higher values between location 3 and 4 is a response to input from Beal's Creek that includes high proportion of Plateau-derived groundwater. Curves A through F in A) depict conservative end-member mixing models discussed in text. Upward limit on brine samples used in diagram is 100,000 mg/L Cl^- (80% of brine data with Br^- data) because mixing models can be constructed within this limit. Complete range of brine salinity values are found in A3.3.

up to around 2,000 mg/L TDS, then decrease with increasing [TDS] to some of the lowest values at [TDS] greater than 7,000 mg/L (Fig. 3.16). Because SO4/TDS values tend to be greater in halite-brines than in produced water (due to sulfate that is associated with halite) the increasing SO4/TDS values suggest that admixing of halite brine is a significant component in shallow groundwater salinity increases up to few thousand mg/L of [TDS], then admixtures of deep-reservoir brine have an increasing influence at higher shallow groundwater [TDS].

It is reasonable to inquire as to the proximity of potential brine sources to aquifers whose groundwater compositional origins are subject to interpretation. Only 3 of the 16 samples with [TDS] greater than 10,000 mg/L are from Permian aquifers that are likely to contain halite. The remaining 13 samples are from the Antlers or Dockum Formations which are continental deposits that are not known to contain significant evaporite, although upward flow into the Antlers and Dockum of brines from halite-bearing Permian aquifers is possible. However, not represented in the groundwater data are analyses of water from the halite-dominated Salado Formation that lies near the top of the Permian section in the study area, understandable because any water-productive interval in the Salado would be insoluble residue after halite dissolution. Based on analyses of Salado water in the Texas Panhandle, groundwater would be strongly a Na-Cl type with [TDS] around 100,000 mg/L, which is about 50% saturated relative to sodium chloride. Thus, there are few practical reasons to complete water wells in the Salado. Based in the few halite brine data that are available from nearby Panhandle wells, however, a case can be made for influence of halite-dissolution brines in study area water.

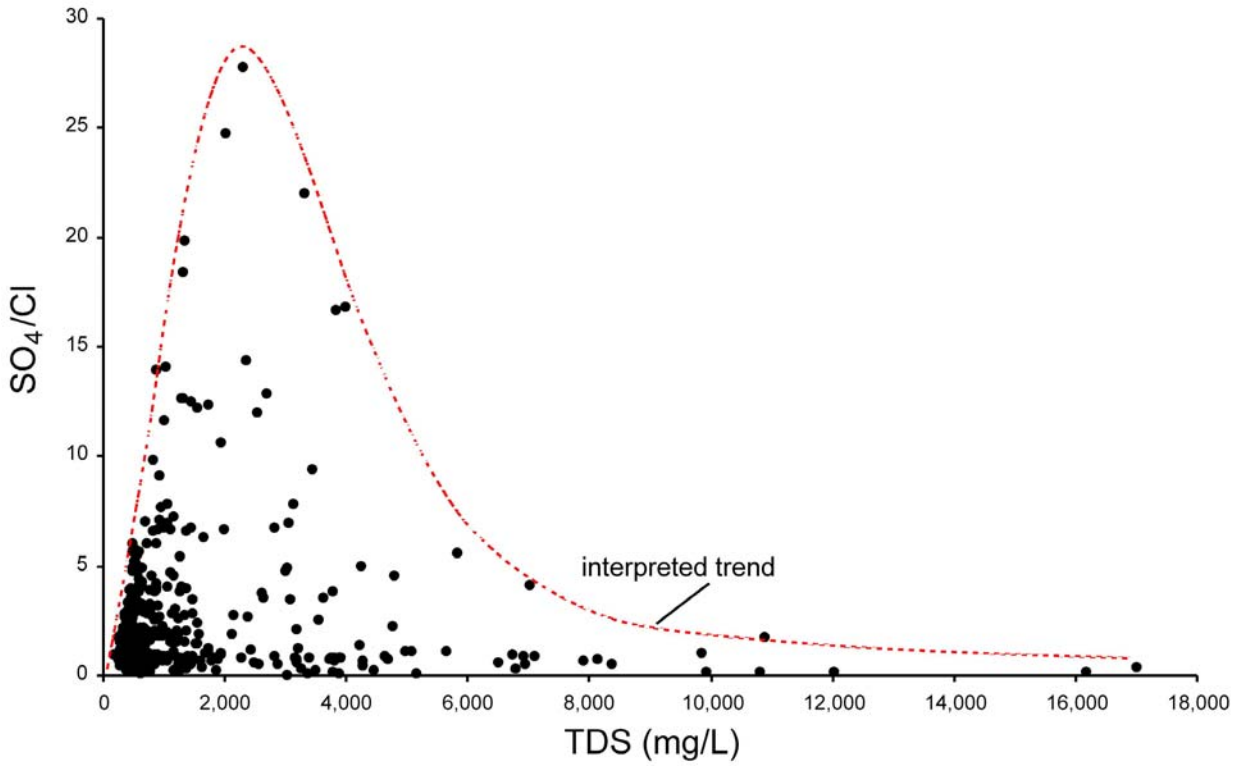

Figure 3.16. Graph showing relationship between SO_4/Cl and salinity in the Dockum aquifer. Overall trend (dashed curve) is interpreted to suggest that many of the waters with up to 3,000 mg/L [TDS] owe increasing salinity, at least in large part, to increasing contribution by halite-dissolution; whereas, higher salinities are due mainly to increased contribution by deep-aquifer brine.

The spatial distribution of Na/Ca values is particularly notable because, within any specific aquifer, Na/Ca values are generally greater near the Colorado River than away from it (Fig. 3.17A). Three hypotheses are suggested by the concentration of Na/Ca values near the river. Either 1) high Na/Ca water is flowing toward the stream in response to the hydraulic gradient indicated by water levels in the shallow aquifers; 2) high Na/Ca stream water is being stored in aquifers near the stream; or 3) high Na/Ca water is rising from deep-brine reservoirs and moving toward the topographically lowest areas. If hypothesis 1) is correct there should be a "trail" of high Na/Ca groundwater leading to the stream configured approximately normal to the hydraulic gradient. This is not evident. If hypothesis 2) is correct there should be some equivocation, at least, over whether the Colorado River is a losing or a gaining stream. The river is a gaining strea most of the time, based on the distribution of hydraulic heads which reflects water-lev data collected over several years (Fig. 3.2). Therefore, the present pattern of hydraulic heads probably characterizes the relationship between the river and adjacent aquifers most of the time. The viability of the third hypothesis is supported by the distribution hydraulic heads in the deep Permian aquifers which have been interpreted to show a potential for upward flow (McNeal, 1965). The calculated fresh-water-equivalent hea actually exceed ground level elevations in several areas in stream valleys (Fig. 3.10). Further, there is a general relationship between the deep-reservoir potentiometric surfa and the distribution of Na/Ca values. The main zone in which Na/Ca exhibits the high values is located near or in the approximately west-east oriented trough in the deep-reservoir potentiometric surface (Fig. 3.17B). This correspondence suggests that the

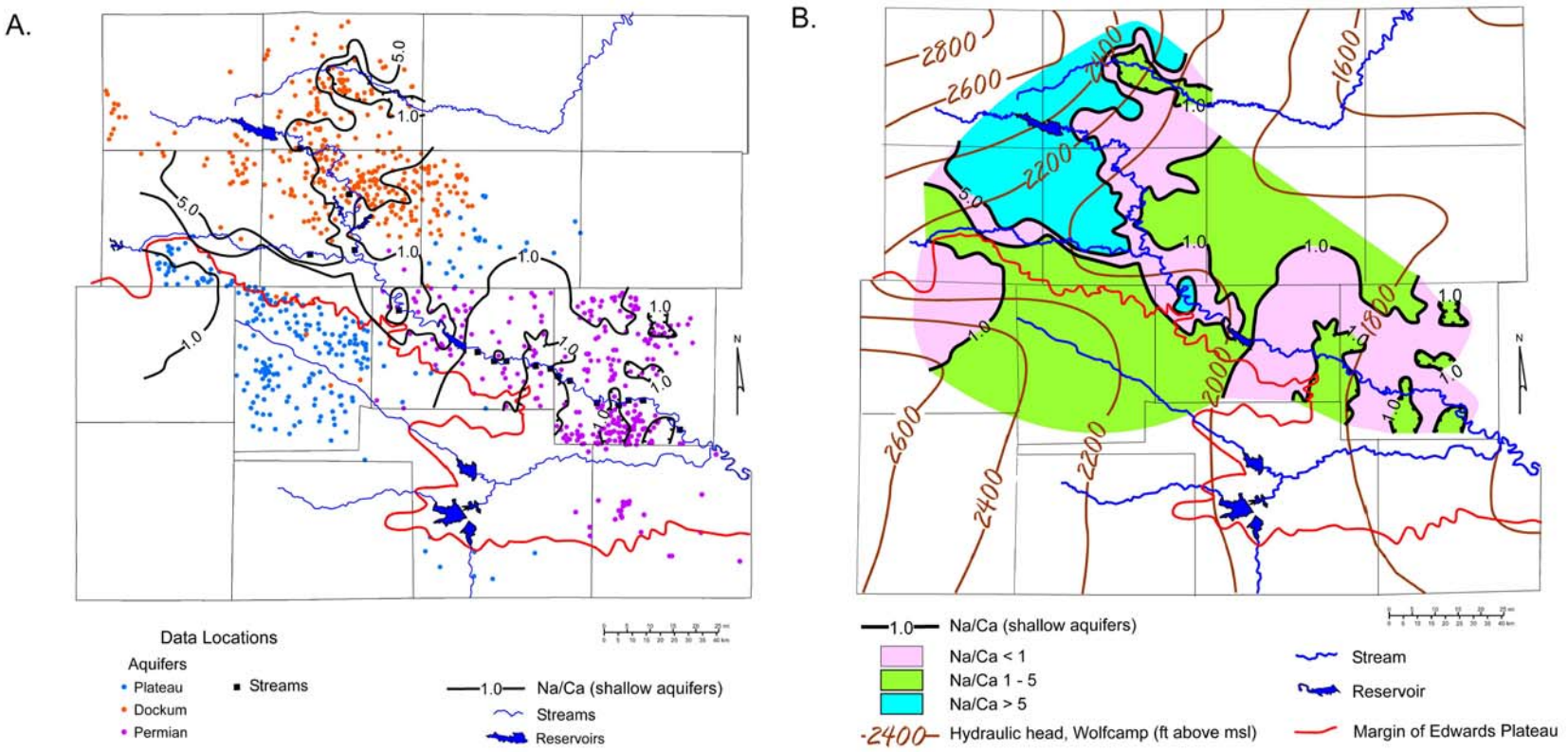

Figure 3.17. Contour maps showing, for shallow aquifers A) Na/Ca value distributions and aquifer-specific data used for map, and B) map of Na/Ca ranges and potentiometric surface of brine in the Wolfcamp aquifer. Maps show elevated Na/Ca values in northwestern part of study area and generally elevated values coincident with topographic low along streams. Extensive area of elevated values in northwestern part of area coincides with prolific oilfield area. Patterns support proposal that brines are propelled upward toward topographic lows under drive from over-pressured deep-brine aquifers.

elevated Na/Ca values reflect contribution to the shallow aquifer system of deep-reservoir brine. Although the deep-brine reservoirs are typically confined, proven by their performance as prolific hydrocarbon traps, conduits to shallower strata or the land surface may be provided by local, deeply penetrating open fractures or poorly sealed wellbores.

Groundwater-Surface Water Interaction

Sources of Elevated Salinity and Causes of Downstream Salinity Decline

The Upper Colorado River traverses terrain underlain by shallow evaporite-bearing Permian rock and is densely populated by hydrocarbon producing operations which have been expanding since the 1920s. Permian Basin hydrocarbon operations are noted for historical disposal of saline fluids both on the land surface, in streams, and in sometimes poorly constructed injection wells. Additionally, the region is semi-arid and salt-concentrating phreatophyte vegetation is locally abundant on flood plains. Therefore, there is no shortage of potential salinity sources and salt-concentrating processes.

The overall decrease downstream in stream salinity corresponds with an east-trending increase in mean annual rainfall (Fig. 3.6). Conceivably, improvement in stream quality may reflect increasing volumes of meteoric recharge. There is a good correlation between mean annual rainfall and stream salinity, including chloride concentration (Fig. 3.18). The correlation between rainfall and chloride is particularly good and may be best explained by a combination of increasing rainfall and decreasing proximity to the most likely sources of high chloride concentrations, which are the halite-dissolution zone (Fig. 3.7) and the long-standing hydrocarbon operations in the Scurry County area (Fig. 3.8)

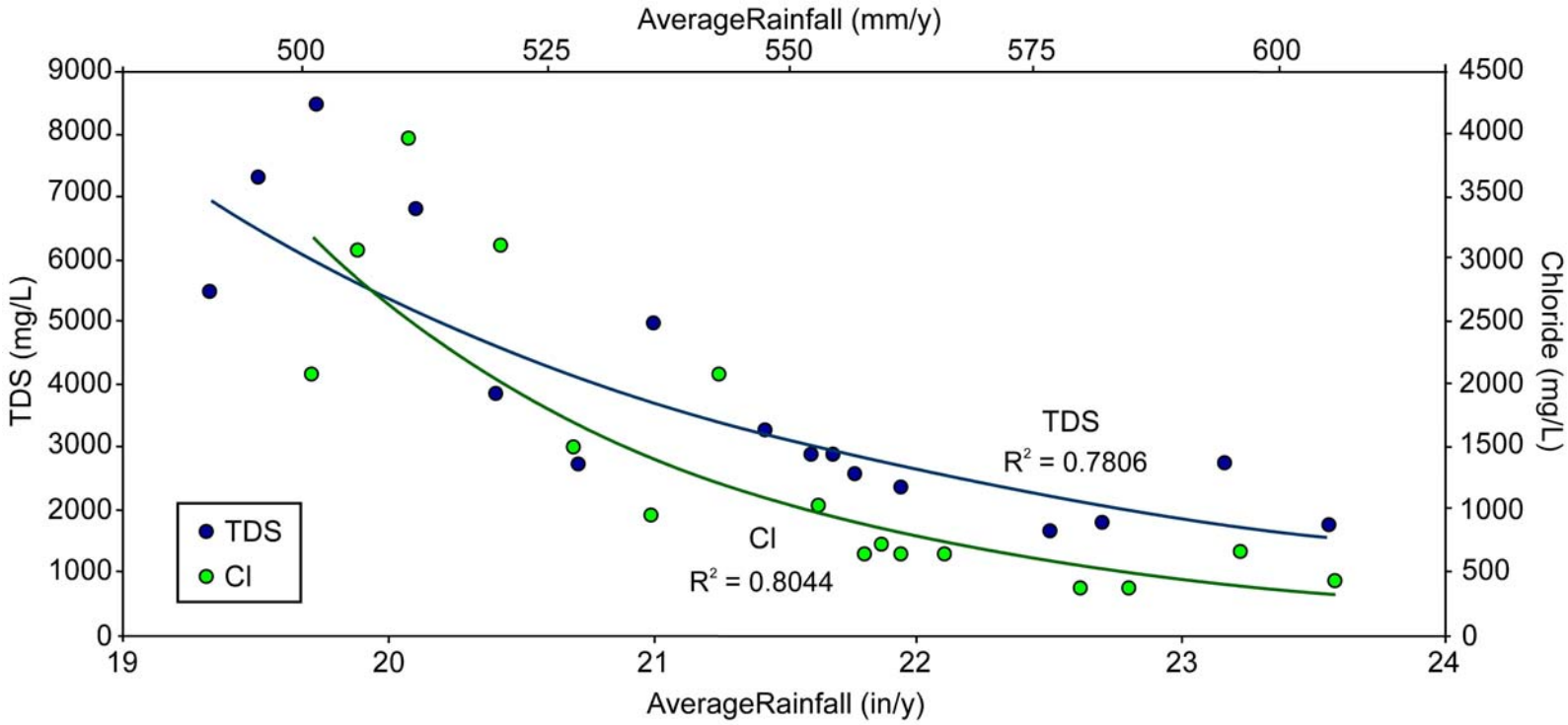

Figure 3.18. Graph showing relationship between [TDS], [Cl^-], and average rainfall at each sample location along the river. Rainfall from Larkin and Bomar (1983). Salinity decrease may reflect increasing downstream baseflow rates arising from increased rainfall rates.

and farther upstream in the northeastern Midland Basin. Local reversals in the downstream decline trend of stream [TDS] and [Cl^-] may be explained by proximity to aerially limited high-salinity sources such as small oilfields. Reed (1961) suggested that fluids in oilfield brine-disposal pits were the main contributor to Upper Colorado River salinity in the more upstream parts of the study area.

Chemically Distinguished River Segmentation Caused by Base Flow Variability

As introduced above, the Upper Colorado River in the study area can be subdivided into 3 segments (upstream, middle, downstream), based on distinguishing hydrochemical characteristics. These characteristics are best expressed in terms of constituent ratios including Na/Cl, Na/Ca, SO_4/Cl, HCO_3/SO_4, Ca/Cl, and B/Cl. These proposed segments maintain their hydrochemically-defined identities in spite of relatively uniform downstream variations in [TDS], [Cl], and Br/Cl.

The upstream segment is represented by the two most saline samples (locations 1 and 2), which also have the highest [Cl], Na/Ca, Na/Cl; and lowest values of Br/Cl, Ca/Cl, B/Cl (Fig. 3.12). The boundary between the upstream and middle segment is placed at location 3 because, while Na/Cl remains elevated at location 3, Na/Ca values decline and Ca/Cl, B/Cl, and SO_4/Cl rise to values more representative of more downstream segments.

Halite-dissolution brine forms a significant fraction of the surface water in the upstream segment where Br/Cl values are much lower than for most produced waters (A3.1). [Br^-] values in halite-dissolution brines are commonly low because halite

crystallization tends to exclude Br^-, and the dissolution products reflect this Br^- deficit. The ranges of Br/Cl values for the Permian Basin halite-dissolution brines for which data was available is 1.7-4.1 (Metha and others, 2000). Brine produced by dissolution of halite produced from seawater collected in the Bahamas has a ranges of Br/Cl $\times 10^4$ of about 1.1 to 3.9 (McCaffrey and others, 1986).

Na/Cl values in the surface waters are quite high compared to most produced waters (A3.1). Na/Cl of pure halite-dissolution brine is about 0.65 and the Na/Cl ranges in the Permian dissolution brines ranges from 0.6 to 68 (median 0.66; A3.1) (Metha and others, 2000).

A significant fraction of deep-brine-aquifer water in the upstream segment is suggested by values of Na/Ca, SO_4/Cl, Br/Cl , and B/Cl. Na/Ca values for all surface samples are less than 8. Na/Ca values for produced waters ranges from 0.93 to 21.01, whereas Na/Ca values for salt-dissolution brines are all greater than 15. Such low Na/Ca values for surface waters indicate that their hydrochemical quality is probably not dominated by halite-dissolution brine. The values for Na/Ca, SO_4/Cl, and Br/Cl in upstream-segment surface water are generally closer to the ranges for produced water than halite-dissolution water. No boron data is available for halite-dissolution brines. However, the ranges of sparse B/Cl ($\times 10^4$) data for produced waters is from 0.86 to 1.07. This compares favorably to the ranges from 1.3 to 1.7 for the upstream segment.

Upstream samples have the lowest SO_4/Cl values of all the surface water samples. Median SO_4/Cl values for deep-reservoir and halite-dissolution brines are 1 to 2 orders of magnitude lower than the medians for any of the shallow-aquifer groundwaters. Although

the upstream segment median SO_4/Cl values are greater than those for either brine types, they are within the ranges for produced water. These values do not indicate that produced water is the sole contributor to river salinity and both brine types probably contribute to groundwater and surface water salinity. However, produced water is probably the more significant brine type.

Upstream surface-water has [TDS] much less than the great majority of brine samples and the greatest fraction of upstream surface water is dominated by the relatively fresher groundwater from the shallow aquifers. In the upstream area, the river traverses the Dockum aquifer which probably is the source for base flow in that area. However, conservative models indicate that much of the flow through the Dockum originates on the Edwards Plateau and, therefore, base flow probably represents a mixture of water from the Plateau system, from the part of the Dockum that is directly recharged by meteoric processes, and from both sources of brine. Most of the Dockum aquifer on the southwest side of the river is recharged by both direct rainfall, discharge from the Plateau system, and brine influx. Parsing the contributors to overall Dockum water quality under these circumstances is too complicated to be exhaustively examined here.

Although upstream SO_4/Cl values approach the upper ranges for deep-reservoir brine, they are generally closer to the values for shallow-aquifer groundwater and support the proposal that brines are not the sole contributors to surface water quality. The important point is that base flow to the Upper Colorado River is dominated by discharge from the Plateau system, an aquifer not in direct contact with the river and that is located more than 30 mi (50 km) away from the upstream segment. Although an outlier of the

Ogallala Formation, an extensive and prolific aquifer elsewhere, parallels the Upper Colorado River in the upstream segment area (Fig. 3.4), most of its discharge is to the Brazos River and has been considered by others (e.g., Slade and Buszka, 1994) to contribute little to the Colorado River.

The middle segment (locations 3 to 7) of the Upper Colorado River is marked by a sharp increases in values of SO_4/Cl, Ca/Cl, Br/Cl, and B/Cl; and decreases in Na/Cl and Na/Ca (Fig. 3.12). Causes for these changes include 1) a diminished relative contribution of halite-dissolution brine; and 2) increasing contributions by Permian $CaSO_4$-evaporite, which is abundant in the Upper Permian and Leonardian sections that are traversed by the river in the middle and downstream segments (Fig. 3.4).

Deep-reservoir brines continue to exert an influence on surface water chemistry in the middle segment, although B/Cl values along the middle segment incrementally increase downstream, thus suggesting a diminishing influence of deep-reservoir brine.

Na/Ca in the middle segment is significantly lower than in the upstream segment where halite-dissolution water is interpreted to contribute a significant fraction. Median Na/Ca values in produced water are significantly lower than those in halite-dissolution water (A3.1), suggesting that the lower Na/Ca values in the middle segment reflect a decreasing influence of halite-dissolution brine.

The middle segment is affected by a greater fraction of groundwater discharging from the Plateau aquifer system than in the upstream segment. The map patterns of SO_4/Cl values (Fig. 3.19) show groundwater with elevated SO_4/Cl, generally characteristic of the Upper Permian system groundwater (Fig. 3.9C), is concentrated to

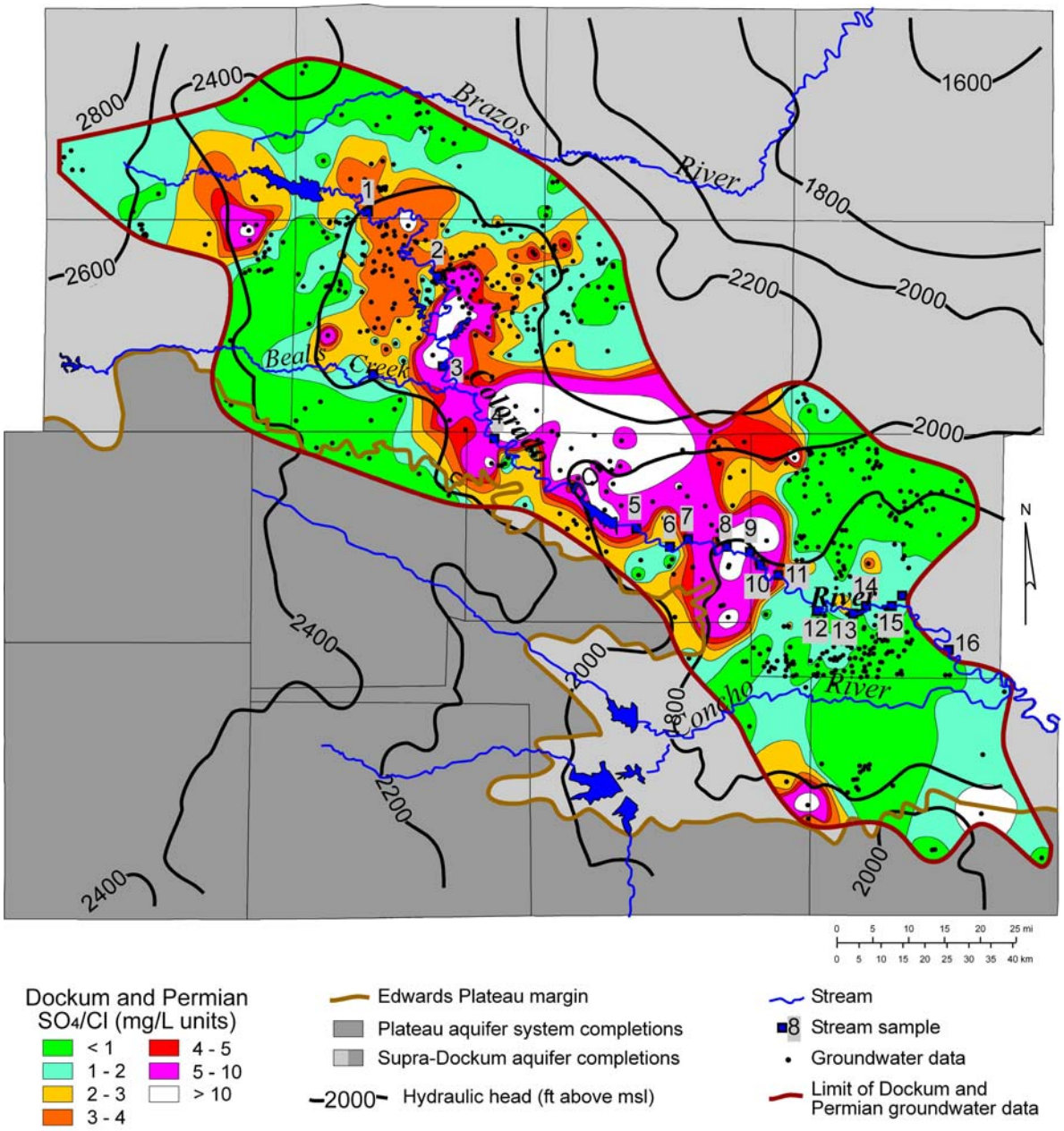

Figure 3.19. Map showing SO_4/Cl distributions from Permian and Dockum shallow aquifers. Purple and white areas depicting most elevated values are almost exclusively in Permian aquifers and probably mark dissolving sulfate evaporite. Asymmetric distribution of SO_4/Cl about river in central part of area is interpreted to mark effect of discharging Plateau system groundwater from the southwest where river most closely approaches the Edwards Plateau. In spite of elevated SO_4/Cl in groundwater in area, surface water maintains relatively low SO_4/Cl values until Plateau margin recedes toward south near stream location 8.

the northeast side of the river, apparently replaced or diluted by significantly lower-SO_4/Cl groundwater discharged from the Plateau system. Discharging Plateau groundwater necessarily flows through the subjacent Dockum aquifer and Permian systems prior to discharging into the river. Corresponding to this area where SO_4/Cl values are asymmetrically distributed about the river, surface water SO_4/Cl values maintain at relatively uniform levels until the river has traversed approximately 40 mi of Upper Permian outcrop at location 7. This suggests that characteristically elevated-SO_4/Cl Permian groundwater is not as greatly affecting base flow chemistry in the middle segment as it does in the downstream segment where the river diverges from the Edwards Plateau.

The sample from location 7 requires note because it is dissimilar to either the middle or downstream segments. Location 7, compared to more upstream locations, shows sharp increases in [TDS], [Cl], Na/Ca, and B/SO_4; and decreases in Br/Cl, SO_4/Cl, Na/Cl, and Ca/Cl. These variations indicate a sharp increase in salinity and an increased brine input. Coincidentally, 1) local water wells have anomalously high [Cl^-] and low SO_4/Cl compared with other groundwaters from the aquifer (San Angelo sandstone member of the Pease River aquifer), and 2) location 7 is very near Wendkirk oilfield. In the section on conservative mixing models it will be shown later that Wendkirk oilfield produced water, the local groundwater, and the location 7 sample can be coupled in a conservative mixing model. These considerations suggest that the location 7 sample represents brine-contaminated water with Wendkirk-type brine composing the

contaminant. Downstream of location 7 most of the aforementioned parameters resume the directional trends reflected in the middle segment.

The downstream segment (locations 8 to16) is defined by sharp increases in SO_4/Cl, Ca/Cl and B/Cl (Fig. 3.12). Br/Cl values continue to rise along the downstream segment, although there is a reduction in the rate of rise. Comparison of Figures 3.12A and 3.12B shows that the rise in values for SO_4/Cl and Br/Cl is largely caused by a reduction in $[Cl^-]$ rather than an increase in $[SO_4^{2-}]$ and $[Br^-]$ which attain some of the lowest values found in the surface water samples analyzed in the investigation. Given the overall relationship between [TDS] and Na/Ca in shallow aquifer groundwaters (Fig. 3.14) and relative elevated Na/Ca values in produced waters (Fig. 3.9) it is proposed that the reduction of middle segment Na/Ca values to their lowest levels in the study area (Fig. 3.12) reflects a continuing loss of influence on stream chemistry by brines and an increasing influence by shallow, relatively uncontaminated groundwater. This conclusion is supported by the overall rise in Na/Cl values in the downstream segment over their ranges in the middle segment, bearing in mind that Na/Cl values in produced water are generally low compared to most values in the shallow aquifers (Fig. 3.9B).

[B] increases significantly in the downstream segment, is especially elevated in the more upstream parts of the downstream segment, and is counter to the trends of the major anions and [TDS] (Fig. 3.12). A plausible explanation for the rise in [B] in the downstream segment is suggested by the average values for [B] in the various shallow aquifers (Fig. 3.20) traversed by the river. The sharp increase in [B] on the more downstream part of the upstream segment may reflect the influence of base flow from the

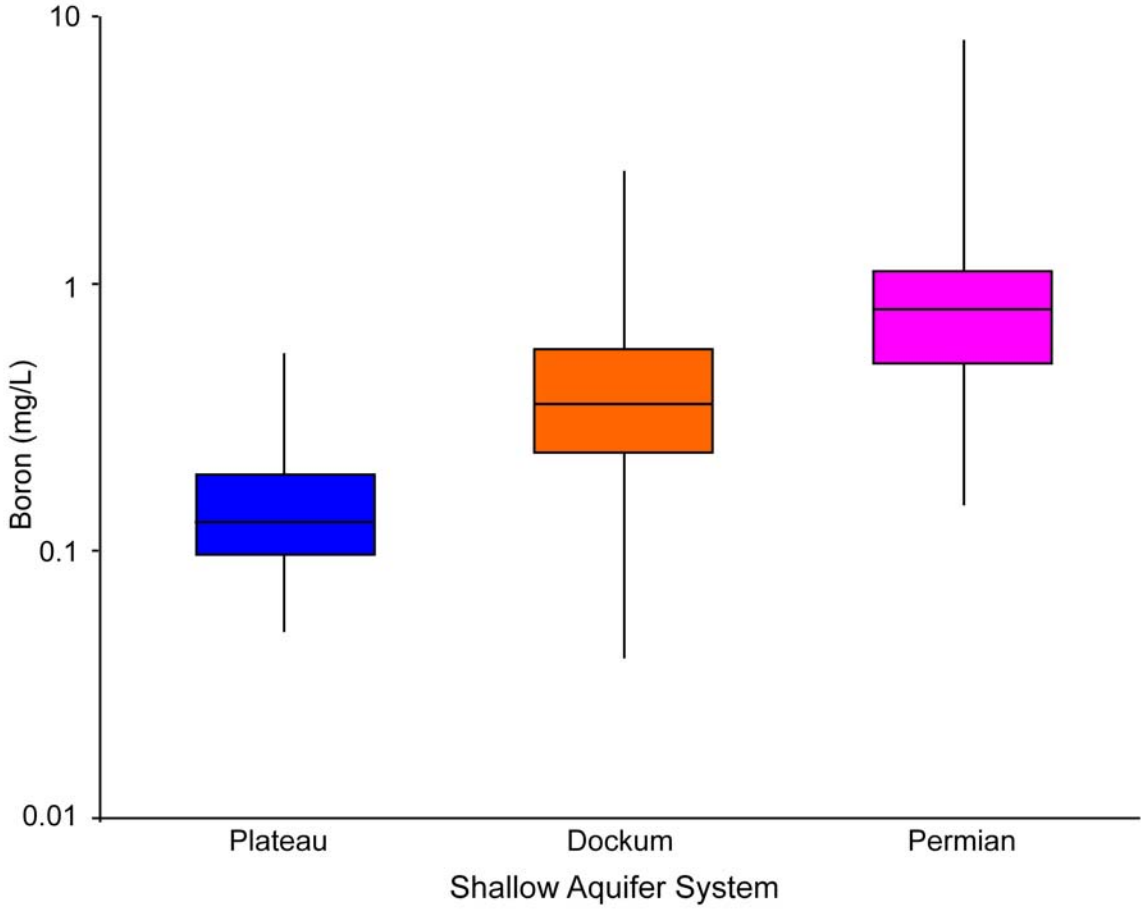

Figure 3.20. Boron concentrations for the shallow aquifers showing total ranges, interquartile ranges, and median values.

Permian system aquifers which show the highest concentrations of B. The downturn in [B] in the more downstream parts of the river may reflect the increasing dominance of Plateau system base flow which shows the lowest overall [B].

Regional Mixing Models

Conservative Mixing Models

Conservative, multi-component mixing models suggest plausible mechanisms for salinity evolution in the Upper Colorado River of Texas that support the conclusions presented above. Model results are supported by geologic features that should influence groundwater chemistry and hydrodynamics.

Conservative mixing models utilize the extreme solubility of certain chemical constituents to interpret the proportions of these constituents in aqueous solutions as recording intermixing of waters from different sources, or of waters that have dissimilar histories prior to mixing. Conservative constituents, by definition, are unlikely to participate in chemical or electrostatic reactions that would remove them from aqueous solution under most natural conditions in near-surface environments. Thus, ratios of conservative constituents are unlikely to vary with changes in pH, temperature, or migration of the host fluid. For example, cation exchange may alter the calcium and sodium concentrations in water that flows through a clay-rich media; however, $[Cl^-]$ or SO_4/Cl are much less likely to be affected. In this investigation conservative ionic constituents that are useful for mixing models include chloride and bromide.

A 2-component mixing model applies the relationship

$$C_{im} = (C_{i1})(F_1) + (C_{i2})(F_2) \quad \text{(E.1)}$$

where C_{im} is the concentration of ion i in the mixture m, C_{i1} is the concentration of ion i in component 1, C_{i2} is the concentration of ion i in component 2, F_1 is the fraction of component 1 the mixture m, and F_2 is the fraction of component 2 in the mixture m. Because F1 + F2 = 1, $F_2 = 1\text{-}F_1$, therefore

$$C_{im} = (C_{i1})(F_1) + (C_{i2})(1\text{-}F_1), \quad \text{(E.2)}$$

which is a linear equation and plots as a line on a graph where $x = F_1$, $y = C_{im}$, and C_{i2} is the y-intercept.

Useful mixing models in this investigation involve constituent ratios that vary with varying F_1 values, generally of the form

$$C_{im}/C_{jm} \quad \text{(E.2)}$$

where C_{jm} is the concentration of ion j in the mixture m. In this report mixing relationships are illustrated by graphs of C_{im}/C_{jm} vs C_{jm} (e.g., Br/Cl vs Cl in Figure 3.15). Non-linear equations are required to describe relationships between component fractions and component ratios in specified mixtures, but they are not discussed here. Mathematical derivation of such models can be found in Faure (1986). For this study, values for ionic ratios were generated by calculations based on concentrations of individual ionic species derived from linear mixing models such as described above.

Figure 3.15A is a graph that shows Br/Cl values and corresponding [Cl^-] concentrations for analyses of water derived from streams, aquifers, and oilfields in the study area. Also included are analyses of 4 halite-dissolution brines sampled from wells

in the Upper Permian halite-dissolution zone in the Texas Panhandle. There are overlaps in the ranges of [Cl^-] and Br/Cl that probably reflect cross-formational mixing between aquifers. The source-specific ranges and relationships between ranges derived from Figure 3.15A are generalized in Figure 3.15B.

Slade and Buszka (1994) used a similar graphic analysis to Figure 3.15A to introduce mixing envelopes that circumscribed all their data and suggested that all the waters in the area could be explained by mixtures of end-member components consisting of various fractions of produced water (included as deep-reservoir brines in their study), shallow-aquifer water, and halite-dissolution brine. The present investigation demonstrates that conservative-ion composition at specific locations in the Upper Colorado River can be explained by mixing between two or more end-member components with actual representatives in the available groundwater and streamwater data set.

Br-Cl Mixing Models for the Upper Colorado River

The following exposition presents a reasonable explanation for downstream-evolving stream chemistry in terms of mixing between multiple groundwater and stream-water types that have representatives in the available dataset (A3.2, A3.3). It is important to note that models that employ more than 2 end members are not unique. However, the exercise demonstrates a viable approach to conceptualizing complex intermixing of waters with different origins and evolutionary histories to account for observed spatial chemical evolution of surface water.

Referring to the sample numbers shown for surface water samples (diamonds in Figure 3.15A) the general downstream trend is toward lower [Cl^-] and higher Br/Cl values. The mixing model shows that the regional trend can be explained by two mixing models (curves A and C in Figure 3.15A) that have one common end-member that is within the range of Permian-system water (P). However, water P is can be generated by mixing model F, reflecting mixing between deep-reservoir brine (represented by PW2) and a Plateau system water (K1). The position of P along mixing model F suggests a composition of greater than 99% Plateau-system groundwater. In other words, the downstream evolutionary trend of the river largely reflects increasing relative contributions of Plateau system groundwater.

Local deviations from the overall trend (e.g., nos. 13 and 14) are suggested to be caused by introduction of groundwater with characteristics somewhat dissimilar to those of groundwater types that dominate the overall trend. Mixing model D suggests mixing between deep-reservoir brine (PW1) and a Plateau-system water (K2) to explain the deviation of samples 13 and 14 from model curve C. This is not a unique solution, however. Samples 13 and 14 also occur on mixing model curve A, thus suggesting that contributions of low Br/Cl deep-reservoir brine, with or without a halite-dissolution-brine fraction, may also explain their compositions.

Two other changes in the overall downstream hydrochemical trends are notable. Whereas samples 1, 2, and 3 trend along mixing model curve A, sample 4 occurs close to curve C. It is suggested that this change reflects input from Beal's Creek (curve B), which receives much of its base flow from the Plateau system that it flow next to (Fig.

3.2) which explains is proximity to mixing model curve F. The position of the Beal's Creek sample relative to the mixing model between the Plateau system sample (K1) and the produced-water end member (PW2) (Fig. 3.15) suggests that the creek sample is composed of approximately 95% Plateau system water and approximately 5% deep-reservoir brine. Beal's Creek intersects the river not far upstream of sample location 4 (Fig. 3.4). The second notable deviation is sample 7 that shows an increase in [Cl^-] and Br/Cl. This can be explained by contributions of brine in the vicinity of Wendkirk oilfield. Sample 7 occurs on a mixing curve defined by Wendkirk produced water and water from several nearby wells that are dominated by Cl^- that is quite dissimilar to SO_4^{2-}-dominated water from other wells in the same aquifer (San Angelo Sandstone of the Pease River Group; Fig. 3.5).

These observations enable insight into manifestation in Br/Cl-Cl space of a mixing system with several to many contributing water types. In situations where multiple mixing model curves intersect (e.g., Figure 3.15) it is possible that a sample that occurs on any of the intersecting curves may contain fractions of end-member components that define each of the models. The mixing system proposed in Figure 3.15 contains 6 separate mixing models, thus it invokes 12 end-members. However, the primary observation is that contributions from the Plateau aquifers appear to dominate the mixing system.

CONCLUSIONS

The Upper Colorado River in semi-arid West Texas is characterized by [TDS], [SO_4^{2-}], and [Cl^-] that are elevated beyond recommended guidelines established by the U. S. Environmental Protection Agency for drinking water. Generally, water quality improves downstream owing to base flow that is increasingly less saline. Base flow salinity improvement is attributed to increasing groundwater discharge arising from increasing recharge rates that reflect increasing meteoric recharge rates near the river and on the nearby Edwards Plateau. Regional groundwater and surface water chemistry in the study area indicate a complex intermixing of multiple water-types including 1) deep-reservoir brines with stratigraphically and geographically varying compositions, 2) chemically more uniform halite-dissolution brines originating from shallow Permian evaporite strata, and 3) chemically diverse groundwaters that traverse multiple shallow Cretaceous-, Triassic-, and Permian-host rock aquifer systems prior to intercepting the river. These conclusions are based on hydrochemical constituent ratios that vary systematically downstream and are supported by conservative (Br/ Cl) groundwater mixing models.

Values for Na/Ca, Na/Cl, and Br/Cl in the most upstream segment suggest that elevated salinity originates from contamination by a mixture of brines similar in composition to local oilfield produced water and halite-dissolution water, respectively. However, the highest concentrations of dissolved solids and individual chemical constituents are far less than that of pure brine end-members and it is most probable that groundwater and surface water generally are dominated by influx of groundwater

discharging from the Edwards Plateau to the east of the river and, subordinately, from the Dockum and Permian system aquifers with which the river is in direct contact. This is particularly evident within the middle segment of the river where SO_4/Cl values in the Permian system are asymmetrically distributed about the river, suggesting that Plateau discharge is displacing typical Permian-sulfate-enriched groundwater to the northeastern side of the stream and replacing it with groundwater with qualities more typical of Plateau and Dockum water. In this area the river is closest to the Edwards Plateau and maintains a non-Permian (low SO_4/Cl) chemical quality, although the aquifer contains Permian-age soluble sulfate-bearing strata.

Although originating largely from the Plateau aquifer system, discharging groundwater traverses Dockum and Permian system aquifers prior to discharging to the river. Downstream of the area where the Edwards Plateau margin is closest to the river, constituent ratios reflect sharply increasing influence of groundwater from stream-adjacent sulfate-evaporite-bearing (SO_4/Cl) Permian aquifers and more remote carbonate-bearing Plateau aquifers (HCO_3/SO_4).

Local (e.g., location 7) sharp increases in stream and groundwater TDS, Cl, Br concentrations, sharp decreases in Br/Cl, HCO_3/SO_4, and SO_4/Cl, and small decreases in Ca/Cl and B/Cl occur near Wendkirk oilfield. Supported by conservative-constituent mixing models, this reversal in downstream trends in river hydrochemistry suggests local contamination of surface water and groundwater by deep-reservoir brine similar to that analyzed from Wendkirk field.

In summary, the hydrochemical evolution along flow of the Upper Colorado River in the study area reflects the mixing of multiple end-member water types with representatives in the available dataset of analyzed local water. Further, many of the candidate groundwater-types thus far identified probably have complex histories of hydrochemical evolution in deep- and shallow aquifers prior to encountering the Colorado River. This recognition reinforces the idea that most natural systems may have exceedingly complicated flow and chemical evolutionary histories and that identification of possible end members may only provide a snapshot within a much larger hydrogeological context that may not be entirely understood. This dilemma may be particularly true in the case of groundwater-surface water interactions where groundwater representing numerous sources and flow paths is entering the surface water system as base flow.

Timing of sample collection is important when investigating near-stream aquifer hydrochemistry for base flow origins. In the event of floods, surface water invades an aquifer system and mixes with the indigenous groundwater, thus producing an atypical hydrochemical environment within the invaded zone. The degree of mixing between normal resident groundwater and the injected surface water, and the time required to completely flush the exotic water after injection is difficult to estimate accurately. Further, the extent of invasion is unknown in any event.

Thus, especially in arid and semi-arid regions, the best time to sample near-stream wells would generally be a times other than those when flooding is significant. In a regional study such as this one where a broad vintage of data is used, knowledge of flow

conditions in specific locations along the river is not easily acquired. Precipitation patterns are capricious and flow conditions recorded at one location, such as is the case in the Upper Colorado system, are probably not representative of the entire watershed.

Fortunately, from the viewpoint of environmental assessment, the presence of significant brine contamination and the dominant brine type (halite-dissolution versus deep-reservoir) can probably be determined. Although not discussed in this paper, deep-reservoir brines in the area differ hydrochemically from one source to another (e.g., Pennsylvanian versus Permian) (e.g., Richter and others, 1990), a characteristic that may be used to more closely identify specific deep-reservoir sources. This analysis is enabled by the understanding that even a small proportion of a highly saline component dominates the conservative-ion ratios of brine-fresh water solutions. It is plausible that the relative influences of halite-dissolution brines and deep-reservoir brines, respectively, might be quantified from interpretations of simple constituent ratios calculated from routine hydrochemical analyses. In an adequately funded and comprehensive investigation samples should be collected expeditiously to avoid climatic complications and appropriate conservative tracers analyzed. Where it is possible to identify deep-reservoir brines as being particularly influential it might also be possible to identify point-sources, such as poorly completed or plugged oil wells, that possibly could be mitigated. Non-point-source contamination by halite-dissolution brine, however, probably has no remedy except for water purification.

FUTURE WORK

Analysis of interacting groundwater and surface water systems is exceeding complex in areas where multiple origins are probable for intermixing water types. This report advances plausible explanations, based on the available data, for hydrochemical variability in groundwater and surface water in the study area. The analysis has been largely statistical and preliminary. Further work includes designing a strategic sampling plan and analyses of conservative (chemical and isotopic) constituents that better constrain possible mixing models. In particular, acquisition of more sophisticated brine (halite-dissolution and deep-aquifer), shallow groundwater, and surface water data from the same geographical areas is particularly important. Use of mixing models such as have been used throughout this dissertation will continue to provide insights into the movement of groundwater from different sources and their respective influence on water quality in specific areas. The ultimate practical objectives of such studies are to determine how people can improve water quality (as in cases where repairable industrial operations are concerned), and to what extent we have to accommodate ourselves to natural factors that we are essentially powerless to mitigate (as in cases of halite dissolution).

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APPENDICES

Appendix 1.1. Plateau system groundwater isotope, TDS, and SO_4/TDS data.

Data: All samples collected by writer for this study.

Appendix 2.1. Edwards aquifer hydrochemical constituent data.

Data: All samples collected by writer for this study.

Appendix 2.2. Edwards aquifer groundwater isotope data.

Data: All samples collected by writer for this study.

Appendix 3.1. Upper Colorado River area shallow-aquifer groundwater hydrochemical summary statistics.

Appendix 3.2. Upper Colorado River area shallow-aquifer groundwater and stream hydrochemical data.

Groundwater data: Slade and Buszka (1994) * All other data: TWDB (2009)
Stream data: All samples collected by writer for this study

Appendix 3.3. Upper Colorado River area produced-water and halite-dissolution brine hydrochemical data.

Data: Slade and Buszka (1994) * Richter and others (1990) **
Mertha and others (2000) + All other data: USGS (2009)

Appendix 1.1. Isotope, TDS, and SO_4/TDS values for Plateau system groundwater samples.

Collection Sequence	Well No.	Co.	Aquifer	$^{87}Sr/^{86}Sr$	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{13}C$ (‰)	^{14}C (pmC)	Tritium (T.U.)	TDS (mg/L)	SO_4/TDS
8	5440201	Crockett	Edwards	0.707961	-4.72	-33.7	-7.0	0.332	0.11	297	0.051
9	5432206	Crockett	Edwards	0.708128	-4.43	-34.8	-5.4	0.155	0.01	439	0.071
10	5432503	Crockett	Edwards	0.708089	-4.44	-33.3	-7.3	0.353	0.39	280	0.050
11	5422901	Crockett	Edwards	0.707853	-4.50	-35.0	-6.0	0.237	0.03	320	0.069
12	5423204	Crockett	Edwards	0.708010	-4.90	-36.5	-8.0	0.427	1.04	412	0.080
13	5431602	Crockett	Edwards	0.708252	-4.94	-36.3	-6.0	0.449	1.14	386	0.057
14	5446502	Crockett	Edwards	0.707907	-5.09	-38.1	-7.0	0.342	0.60	286	0.059
15	5438903	Crockett	Edwards	0.708447	-5.01	-36.6	-7.8	0.507	0.90	306	0.039
16	5445201	Crockett	Edwards	0.708132	-5.32	-39.5	-9.5	0.586	1.62	518	0.068
17	5444401	Crockett	Edwards	0.708340	-4.50	-36.0	-5.4	0.159	0.18	287	0.087
18	5414503	Crockett	Edwards	0.707883	-4.72	-35.8	-6.6	0.328	0.83	603	0.060
19	5405406	Crockett	Edwards	0.708518	-6.12	-45.4	-6.6	0.071	0.09	2167	0.334
20	5411512	Crockett	Edwards	0.707995	-5.86	-44.4	-9.8	0.541	1.93	839	0.226
21	5403506	Crockett	Edwards	0.708083	-5.87	-41.7	-6.0	0.703	3.28	433	0.185
22	5411306	Crockett	Edwards	0.708226	-7.49	-52.8	-6.0	0.113	0.02	823	0.369
38	5525902	Sutton	Edwards	0.707908	-5.05	-34.3	-11.1	0.548	0.99	322	0.062
39	5545307	Sutton	Edwards	0.708291	-5.36	nd	-10.2	0.410	0.50	258	0.031
40	5522901	Sutton	Edwards	0.707891	-4.69	-32.1	-7.0	0.216	0.12	295	0.068
41	5530402	Sutton	Edwards	0.707922	-5.02	-34.2	-8.1	0.333	0.00	245	0.049
42	5547701	Edwards	Edwards	0.707975	-4.91	-31.7	-9.0	0.430	0.68	361	0.028
43	5541202	Sutton	Edwards	0.707921	-4.98	-31.7	-9.6	0.600	1.06	351	0.051
44	5527603	Sutton	Edwards	0.707954	-5.17	-35.6	-9.3	0.611	1.14	300	0.037
45	5513905	Schleicher	Edwards	0.708029	-5.00	-32.1	-9.2	0.393	1.55	286	0.052
46	5505504	Schleicher	Edwards	0.708157	-4.89	-34.6	-9.4	0.592	1.56	314	0.038
47	5509503	Schleicher	Edwards	0.707976	-5.05	-33.6	-7.9	0.472	0.99	289	0.066
48	5502508	Schleicher	Edwards	0.707691	-5.16	-34.7	-6.6	0.283	0.16	264	0.102
49	5503104	Schleicher	Edwards	0.708088	-4.23	-32.8	-6.5	0.125	0.13	292	0.075
50	4359701	Schleicher	Edwards	0.707938	-5.29	-36.1	-6.7	0.296	0.22	287	0.063
51	5503603	Schleicher	Edwards	0.708026	-4.85	-31.8	-6.3	0.198	0.07	333	0.081
		Average for Edwards		0.708055	-5.09	-36.3	-7.6	0.373	0.74	434	0.090

Collection Sequence	Well No.	Co.	Aquifer	$^{87}Sr/^{86}Sr$	$\delta^{18}O$ (‰)	δD (‰)	$\delta^{13}C$ (‰)	^{14}C (pmC)	Tritium (T.U.)	TDS (mg/L)	SO_4/TDS
7	4426216	Upton	Antlers	0.708674	-8.82	-65.1	nd	nd	nd	1792	0.535
23	4413152	Glasscock	Antlers	0.708703	-5.78	-42.4	-7.8	0.223	0.13	432	0.197
24	4420354	Glasscock	Antlers	0.708502	-4.75	-43.7	-7.9	0.502	1.23	2250	0.312
25	4420549	Glasscock	Antlers	0.708687	-6.74	-48.9	-8.0	0.325	0.46	1750	0.445
26	4419310	Glasscock	Antlers	0.708721	-6.07	-42.3	-8.3	0.240	0.07	650	0.297
27	4418612	Glasscock	Antlers	0.708768	-6.64	-48.7	-8.3	0.213	0.08	734	0.394
28	4412409	Glasscock	Antlers	0.708706	-5.43	-39.6	-8.0	0.497	0.35	1108	0.323
29	4404905	Glasscock	Antlers	0.708629	-5.37	-38.6	-7.4	0.244	0.08	397	0.196
31	4405119	Glasscock	Antlers	0.708737	-5.50	-40.8	-8.0	0.351	0.13	400	0.158
35	4411310	Glasscock	Antlers	0.708691	-5.22	-40.6	-7.6	0.505	0.02	467	0.193
36	4413321	Glasscock	Antlers	0.708739	-6.60	-50.7	-8.4	0.374	1.07	983	0.384
37	4421611	Glasscock	Antlers	0.708489	-4.42	-35.1	-5.8	0.174	0.00	350	0.263
54	4452102	Reagan	Antlers	0.708634	-8.24	-45.0	-3.1	0.044	0.04	3697	0.236
55	4442328	Reagan	Antlers	0.708679	-7.89	-52.8	-4.7	0.289	0.28	1869	0.556
57	4437109	Reagan	Antlers	0.708676	-7.01	-50.5	-6.4	0.081	0.16	754	0.389
60	4451102	Reagan	Antlers	0.708576	-8.48	-59.1	-8.2	0.057	0.00	2098	0.586
65	4429724	Reagan	Antlers/Dockum	0.708557	-5.10	-34.2	-6.2	0.249	0.21	nd	nd
		Average for Antlers		0.708657	-6.36	-45.8	-7.1	0.273	0.27	1233	0.341

Appendix 2.1. Edwards groundwater hydrochemical constituent analyses (mg/L).

Well No.	Co.	LatDD	LongDD	Si	Ca	Mg	Na	K	Sr	HCO_3	SO_4	Cl	F	NO_3	pH	TDS
5440201	Crockett	30.4726	-101.0829	17	63	25	17	0.8	0.73	268	15	22	0.6	4.87	7.1	297
5432206	Crockett	30.6244	-101.0697	18	60	35	59	2.0	0.74	256	31	92	1.3	14.17	7.4	439
5432503	Crockett	30.5490	-101.0747	15	65	21	12	0.9	0.44	250	14	14	0.4	15.49	7.4	280
5422901	Crockett	30.6441	-101.2706	20	56	28	20	1.5	1.44	247	22	32	2.3	15.94	7.4	320
5423204	Crockett	30.7127	-101.1978	18	86	20	40	2.4	1.09	278	33	61	0.9	12.84	6.7	412
5431602	Crockett	30.5579	-101.1659	22	85	23	27	2.1	0.64	308	22	40	0.6	12.84	6.9	386
5446502	Crockett	30.3021	-101.3170	15	55	27	13	1.2	6.14	261	17	16	1.6	5.76	6.9	286
5438903	Crockett	30.3986	-101.2795	21	77	18	12	0.9	0.27	281	12	16	0.4	11.51	6.9	306
5445201	Crockett	30.3758	-101.4532	21	92	21	74	2.3	1.00	303	35	112	0.6	10.18	7.2	518
5444401	Crockett	30.3126	-101.6085	16	45	26	21	1.0	4.08	211	25	30	2.4	12.40	7.4	287
5414503	Crockett	30.8038	-101.3020	17	77	29	113	3.2	1.43	271	36	183	1.1	8.85	7.1	603
5405406	Crockett	30.9413	-101.4636	9	134	115	478	15.9	4.06	351	723	512	2.6	< 0.44	7.2	2166
5411512	Crockett	30.8201	-101.6778	27	130	51	100	4.4	3.73	349	190	152	1.0	8.85	6.8	839
5403506	Crockett	30.9511	-101.6948	28	97	22	22	4.5	1.78	281	80	30	0.4	8.85	7.0	433
5411306	Crockett	30.8705	-101.6461	11	91	60	116	5.7	2.65	288	304	89	1.9	< 0.44	7.0	823
5547701	Edwards	30.2820	-100.2309	14	54	19	10	0.9	0.72	239	10	13	0.4	4.43	7.4	361
4452505	Reagan	31.1886	-101.5458	29	90	10	74	3.2	0.78	325	55	64	1.1	6.20	8.0	492
4452507	Reagan	31.1947	-101.5464	42	247	45	253	4.9	4.70	393	344	484	2.4	33.65	7.6	1654
4453602	Reagan	31.1908	-101.4139	10	129	89	198	8.2	11.20	264	701	184	3.7	< 0.44	7.8	1464
5513905	Schleicher	30.7676	-100.3995	15	60	22	13	1.4	1.71	276	15	15	0.5	6.20	7.4	286
5505504	Schleicher	30.9403	-100.4383	14	73	20	16	1.5	0.54	283	12	26	0.3	11.95	7.4	314
5509503	Schleicher	30.8181	-100.9566	17	61	20	16	1.8	1.83	256	19	17	0.4	9.30	7.4	289
5502508	Schleicher	30.9464	-100.8139	14	50	24	13	2.0	2.67	215	27	17	2.1	6.64	7.5	264
5503104	Schleicher	30.9781	-100.7299	15	45	28	22	1.7	0.41	215	22	31	0.7	20.81	7.6	292
4359701	Schleicher	31.0370	-100.7313	15	60	25	15	1.7	0.62	256	18	18	0.6	7.53	7.5	287
5503603	Schleicher	30.9449	-100.6521	14	53	28	30	1.7	0.97	215	27	53	0.8	17.71	7.5	333
5525901	Sutton	30.5120	-100.9003	17	72	21	16	1.8	2.26	276	20	24	0.6	11.95	7.1	322
5545307	Sutton	30.3592	-100.3981	14	53	24	10	1.3	0.24	261	8	15	0.3	3.54	7.2	258
5522901	Sutton	30.6426	-100.2509	17	48	29	21	1.3	4.43	238	20	27	0.9	9.30	7.4	295
5530402	Sutton	30.5622	-100.3470	13	45	26	11	0.9	1.44	239	12	14	0.7	3.54	7.4	245
5541202	Sutton	30.3511	-100.9436	17	84	20	14	1.8	1.84	308	18	20	0.5	10.18	7.0	338
5527603	Sutton	30.5749	-100.6424	15	72	20	11	1.5	1.37	298	11	15	0.3	7.08	7.2	300

Appendix 2.2. Edwards groundwater isotope analyses.

Well No.	County	LatDD	LongDD	$^{87}Sr/^{86}Sr$	tritium (T.U.)	$\delta^{13}C$ (‰)	^{14}C (pmC)
5403506	Crockett	30.9511	-101.6948	0.70808	3.28	-6.0	0.703
5405406	Crockett	30.9413	-101.4636	0.70852	0.09	-6.6	0.071
5411306	Crockett	30.8705	-101.6461	0.70823	0.02	-6.0	0.113
5411512	Crockett	30.8201	-101.6778	0.70800	1.93	-9.8	0.541
5414503	Crockett	30.8038	-101.3020	0.70788	0.83	-6.6	0.328
5422901	Crockett	30.6441	-101.2706	0.70785	0.03	-6.0	0.237
5423204	Crockett	30.7127	-101.1978	0.70801	1.04	-8.0	0.427
5431602	Crockett	30.5579	-101.1659	0.70825	1.14	-6.0	0.449
5432206	Crockett	30.6244	-101.0697	0.70813	0.01	-5.4	0.155
5432503	Crockett	30.5490	-101.0747	0.70809	0.39	-7.3	0.353
5438903	Crockett	30.3986	-101.2795	0.70845	0.90	-7.8	0.507
5440201	Crockett	30.4726	-101.0829	0.70796	0.11	-7.0	0.332
5444401	Crockett	30.3126	-101.6085	0.70834	0.18	-5.4	0.159
5445201	Crockett	30.3758	-101.4532	0.70813	1.62	-9.5	0.586
5446502	Crockett	30.3021	-101.3170	0.70791	0.60	-7.0	0.342
5547701	Edwards	30.2820	-100.2309	0.70798	0.68	-9.0	0.430
4452505	Reagan	31.1886	-101.5458	0.70865	3.58	-8.5	1.002
4452507	Reagan	31.1947	-101.5464	0.70854	3.30	-10.5	0.860
4453602	Reagan	31.1908	-101.4139	0.70796	<0.1	-3.0	0.039
4359701	Schleicher	31.0370	-100.7313	0.70794	0.22	-6.7	0.296
5502508	Schleicher	30.9464	-100.8139	0.70769	0.16	-6.6	0.283
5503104	Schleicher	30.9781	-100.7299	0.70809	0.13	-6.5	0.125
5503603	Schleicher	30.9449	-100.6521	0.70803	0.07	-6.3	0.198
5505504	Schleicher	30.9403	-100.4383	0.70816	1.56	-9.4	0.592
5509503	Schleicher	30.8181	-100.9566	0.70798	0.99	-7.9	0.472
5513905	Schleicher	30.7676	-100.3995	0.70803	1.55	-9.2	0.393
5522901	Sutton	30.6426	-100.2509	0.70789	0.12	-7.0	0.216
5525902	Sutton	30.5120	-100.9003	0.70791	0.99	-11.1	0.548
5527603	Sutton	30.5749	-100.6424	0.70795	1.14	-9.3	0.611
5530402	Sutton	30.5622	-100.3470	0.70792	<0.1	-8.1	0.333
5541202	Sutton	30.3511	-100.9436	0.70792	1.06	-9.6	0.600
5545307	Sutton	30.3592	-100.3981	0.70829	0.50	-10.2	0.410

Appendix 3.1. Summary of groundwater hydrochemical statistical parameters

Halite-Dissolution Brine	TDS (mg/L)	HCO3 (mg/L)	SO4 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	HCO3/SO4	SO4/Cl	Ca/Cl	Na/Cl	Na/Ca	Br/Cl	B/Cl	B/SO4
n	-	4	6	6	6	-	4	6	6	6	6	6	-	-
Range	-	39-72.6	4,725-5,900	35,100-170,400	6.2-58	-	0.007-0.02	0.03-0.17	0.009-0.04	0.60-0.68	15.7-74.1	0.0002-0.0004	-	-
Median	-	53.5	5,655	53,900	21.7	-	0.01	0.09	0.04	0.66	17.8	3.000E-04	-	-
Standev	-	17.15	454.6	64,847	22.09	-	0.004	0.06	0.02	0.03	27.1	9.510E-05	-	-
Produced Water														
n	1,457	1,476	1,482	1,493	34	3	1,467	1,482	1,493	1,450	1,450	34	3	3
Range	10,075-371,725	1-2,948	2-7,358	5,188-230,673	9.9-480	3.2-7.45	0.0004-232	1.58E-05-0.66	0.012-0.32	0.02-1.59	0.93-43.03	0.0009-0.01	9.23E-05-0.11	0.006-0.02
Median	97,718	216	932	58,346	78	6.3	0.24	0.013	0.08	0.53	6.42	0.002	9.00E-02	0.018
Standev	46,780	258	1,223	29,677	163.6	2.2	13.2	0.056	0.029	0.06	4.02	0.002	0.06	-
Plateau System														
n	128	256	256	256	39	48	256	256	252	246	245	39	48	49
Range	210-10,256	82-483	4-1,492	7-16,330	0.03-3.87	0.049-0.54	0.18-79.25	0.03-60.3	0.02-18.2	0.21-2.77	0.064-43.2	0.002-0.01	7.42E-05-2.0E-02	4.76E-05 - 0.012
Median	311	262	23.5	23.05	0.14	0.129	11.13	0.92	2.68	0.82	0.33	0.005	0.005	0.005
Standev	1,035	56.4	160.6	1,446	0.696	0.095	10.4	3.85	2.39	0.34	2.87	0.002	0.004	0.003
Dockum														
n	379	367	380	380	82	164	366	379	380	379	379	82	164	164
Range	185-17,007	7.32-756.2	0-4,700	7-15,500	0.078-37	0.04-2.06	0.02-42.9	0.05-27.78	0.0008-9.09	0.15-12.77	0.04-1.385	7.98E-05-0.026	0.0001-0.03	0.00004-0.025
Median	827	297	193	101	0.53	0.357	1.54	1.6	0.97	1.02	1.03	0.005	0.005	0.002
Standev	2,135	93	655	1,227	5.11	0.427	5.32	3.64	1.4	1.35	75.99	0.004	0.005	0.004
Upper Permian														All Permian
n	38	33	38	38	5	5	33	38	38	38	38	5	5	20
Range	329-5,224	24-406	23-2,450	120-1,600	0.9-8	0.21-0.96	0.01-17.4	0.07-46	0.15-17.4	0.14-2.81	0.06-3.92	0.002-0.01	0.0003-0.003	0.00014-0.002
Median	2,417	222	1,180	106	1.7	0.45	0.17	3.71	1.54	0.73	0.39	0.006	0.002	0.0006
Standev	1,366.50	90.8	761	426.7	2.9	0.28	3.63	10.38	3.67	0.45	0.69	0.003	0.001	0.0006
Pease River														
n	22	18	22	22	4	7	18	22	22	22	22	4	4	-
Range	455-85,397	206-504	23-4,100	37-49,400	1.5-7.3	0.15-5.8	0.06-16.55	0.07-19.64	0.036-2.326	0.34-9.56	0.31-137.5	0.002-0.005	0.002-0.005	-
Median	2.059	364	830	223	3.45	1.4	0.56	1.76	0.769	0.74	1.36	0.004	0.004	-
Standev	23,597	86	1,280	13,787	2.45	1.9	3.82	4.45	0.63	2.11	28.8	0.001	0.001	-
Leonardian														
n	242	237	242	242	5	6	237	242	242	242	242	5	5	-
Range	204-7,200	51-540	6-2,500	5-3,100	1.9-7.9	0.63-1.1	0.05-34.17	0.075-41.29	0.12-12.8	0.17-4.8	0.16-4.07	0.003-0.005	0.0005-0.002	-
Median	1,531	272	234	384	4.9	0.84	1.35	0.6	0.54	0.52	1.02	0.004	0.0007	-
Standev	1,041	66.4	471.8	407.3	2.48	0.18	2.58	4	1.4	0.45	0.54	0.0009	0.0006	-

Appendix 3.2. Hydrochemical database for Upper Colorado River area surface water and shallow-aquifer groundwater.

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
1	Scurry	-101.0549	32.5389	stream	-	392	160	2,480	6.6	1,280	299	3,950	3.860	<0.53	8,430	8.1
2	Mitchell	-100.8942	32.3999	stream	-	266	133	2,080	7.7	1,090	224	3,090	3.390	<0.53	6,790	8.2
3	Mitchell	-100.8728	32.2099	stream	-	347	161	1,150	8.2	1,460	312	1,604	2.250	0.498	4,890	8.2
4	Coke	-100.7362	32.0197	stream	-	397	174	1,310	10.7	1,370	271	2,080	4.500	0.509	5,500	8.1
5	Coke	-100.4808	31.8854	stream	-	272	146	909	16.5	861	221	1,505	4.190	0.505	3,830	8.1
6	Coke	-100.4232	31.8509	stream	-	205	113	607	13.1	700	213	974	3.370	0.390	2,730	8.1
7	Coke	-100.3796	31.8581	stream	-	279	185	1,250	16.8	1,030	204	2,070	5.630	0.742	4,950	8.0
8	Coke	-100.2920	31.8479	stream	-	319	138	646	12.0	1,010	238	1,038	3.030	0.834	3,300	8.0
9	Coke	-99.2404	31.8288	stream	-	378	121	398	9.2	1,190	228	637	2.000	0.798	2,870	8.0
10	Runnels	-100.2178	31.8092	stream	-	342	125	474	9.5	1,030	263	728	2.290	0.656	2,860	8.1
11	Runnels	-100.1846	31.7926	stream	-	304	125	407	8.4	971	221	639	2.050	0.774	2,580	8.1
12	Runnels	-99.1074	31.7227	stream	-	251	119	402	8.7	848	208	635	1.940	0.670	2,380	8.3
13	Runnels	-100.0274	31.7147	stream	-	216	90	231	6.5	609	239	383	1.110	0.438	1,667	8.1
14	Runnels	-99.9993	31.7318	stream	-	256	92	220	3.8	685	270	373	1.160	0.417	1,792	8.0
15	Runnels	-99.9416	31.7299	stream	-	350	133	408	7.5	1,030	262	659	2.210	0.571	2,750	8.1
16	Runnels	-99.8323	31.6359	stream	-	201	97	267	4.6	566	291	433	1.640	0.383	1,739	8.2
Beal's Creek	Howard	-101.0138	32.1993	stream	-	425	358	1,720	22.0	1,500	344	3,060	14.260	0.923	7,280	8.1
				Aquifer (TWDB)												
2852603	Howard	-101.5125	32.1903	218ALRS	21	145	32	134	-	241	245	202	-	-	938	7.3
2852903	Howard	-101.5064	32.1639	218ALRS	29	359	134	476	-	905	200	900	-	-	2,996	7.2
2852904	Howard	-101.5125	32.1594	218ALRS	32	242	94	362	-	630	483	475	-	-	2,102	7.1
2852905	Howard	-101.5125	32.1597	218ALRS	30	164	41	208	7.7	396	287	194	1.380	0.540	1,263	7.2
2852909	Howard	-101.5078	32.1436	218ALRS	22	102	10	44	-	46	298	44	-	-	450	7.5
2853103	Howard	-101.4789	32.2164	218ALRS	-	194	19	134	4.0	185	281	260	-	-	951	8.2
2853104	Howard	-101.4772	32.2167	218ALRS	23	178	20	123	4.5	167	301	261	1.900	0.113	941	7.0
2853106	Howard	-101.4661	32.2094	218ALRS	19	122	3	61	-	98	277	75	-	-	543	7.6
2853202	Howard	-101.4225	32.2267	218ALRS	17	67	7	27	-	29	233	23	-	-	288	7.6
2853301	Howard	-101.3967	32.2481	218ALRS	31	54	19	71	-	51	305	47	-	-	424	7.5
2853304	Howard	-101.4106	32.2447	218ALRS	19	65	16	58	-	38	277	68	-	-	401	7.6
2853401	Howard	-101.4761	32.2014	218ALRS	18	80	10	54	-	62	257	58	-	-	416	7.9

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2853403	Howard	-101.4672	32.1917	218ALRS	20	71	14	68	-	80	226	76	-	-	449	7.4
2853501	Howard	-101.4453	32.2078	218ALRS	19	78	4	17	-	23	232	22	-	0.220	281	6.6
2853705	Howard	-101.4686	32.1614	218ALRS	-	46	5	44	-	4	232	26	-	-	239	-
2853708	Howard	-101.4875	32.1600	218ALRS	18	150	42	204	-	325	309	274	-	-	1,175	7.6
2853709	Howard	-101.4594	32.1394	218ALRS	13	71	8	134	-	99	211	148	-	-	591	7.8
2853711	Howard	-101.4625	32.1564	218ALRS	21	254	30	145	7.0	311	329	344	-	-	1,288	7.5
2853712	Howard	-101.4614	32.1558	218ALRS	-	277	18	173	6.9	400	410	260	-	-	1,347	7.9
2853714	Howard	-101.4747	32.1494	218ALRS	21	221	71	387	-	520	339	570	-	-	1,976	7.6
2853716	Howard	-101.4778	32.1350	218ALRS	16	61	18	156	-	115	256	156	-	-	658	7.8
2854403	Howard	-101.3469	32.1839	218ALRS	22	61	7	37	-	32	218	27	-	-	297	7.8
2854701	Howard	-101.3408	32.1425	218ALRS	18	76	8	19	-	19	261	18	-	-	288	7.2
2854702	Howard	-101.3419	32.1264	218ALRS	16	79	11	37	-	33	278	37	-	-	353	7.5
2854804	Howard	-101.3133	32.1347	218ALRS	17	72	11	34	-	32	264	29	-	-	328	7.5
2861105	Howard	-101.4842	32.0947	218ALRS	13	82	16	137	-	132	232	160	-	-	672	7.7
2861106	Howard	-101.4850	32.1247	218ALRS	16	92	34	144	-	156	281	187	-	-	782	7.7
2861202	Howard	-101.4469	32.0944	218ALRS	14	67	4	18	1.0	26	201	24	-	-	260	7.7
2861203	Howard	-101.4178	32.1147	218ALRS	17	66	8	25	-	23	231	22	-	-	277	7.4
2861306	Howard	-101.3814	32.0942	218ALRS	16	175	24	292	-	67	222	670	-	-	1,361	7.5
2861310	Howard	-101.3844	32.1011	218ALRS	16	257	57	840	-	214	233	1,640	-	-	3,145	7.5
2862101	Howard	-101.3642	32.1069	218ALRS	17	99	11	99	-	55	219	184	-	-	583	6.8
2862102	Howard	-101.3633	32.1083	218ALRS	15	130	12	174	-	66	214	367	-	-	885	6.7
2862104	Howard	-101.3656	32.1092	218ALRS	-	105	11	61	-	48	231	120	-	-	473	8.3
2862105	Howard	-101.3653	32.1136	218ALRS	17	113	17	167	3.2	106	226	301	1.180	0.144	850	7.3
2862106	Howard	-101.3656	32.1128	218ALRS	18	92	12	96	2.4	66	225	180	0.374	0.129	588	7.2
2862110	Howard	-101.3497	32.1011	218ALRS	16	447	60	1,130	-	169	204	2,460	-	-	4,390	7.4
2862112	Howard	-101.3397	32.1092	218ALRS	15	1,020	93	2,720	-	391	229	5,900	-	-	10,256	7.3
2862113	Howard	-101.3692	32.1119	218ALRS	26	117	4	60	-	67	249	98	-	-	518	7.7
2862114	Howard	-101.3686	32.1128	218ALRS	3	72	14	94	-	150	82	162	-	-	537	7.3
2862301	Howard	-101.2761	32.0950	218ALRS	18	73	9	24	-	27	247	26	-	-	303	7.5
2862305	Howard	-101.2897	32.0881	218ALRS	18	90	9	14	-	17	268	31	-	-	318	7.7
2862306	Howard	-101.2714	32.1061	218ALRS	18	82	9	19	-	17	277	24	-	-	306	7.6

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2862309	Howard	-101.2714	32.1031	218ALRS	18	180	14	137	-	21	260	404	-	-	907	7.4
2862606	Sterling	-101.2517	32.0669	218ALRS	20	87	8	23	-	21	285	21	-	-	329	7.6
2863103	Sterling	-101.2175	32.0853	218ALRS	17	58	3	13	-	11	189	15	-	-	210	7.5
2863203	Sterling	-101.1978	32.0853	218ALRS	9	38	11	85	-	73	112	115	-	-	388	6.6
2863402	Sterling	-101.2283	32.0786	218ALRS	18	95	4	21	-	20	289	24	-	-	327	7.6
2863404	Sterling	-101.2231	32.0625	218ALRS	18	107	3	22	-	19	323	25	-	-	358	7.5
2863501	Sterling	-101.2022	32.0708	218ALRS	15	86	4	18	-	16	268	19	-	-	292	7.6
2863502	Sterling	-101.1717	32.0794	218ALRS	20	81	5	17	-	15	261	16	-	-	285	7.7
2863503	Sterling	-101.1819	32.0483	218ALRS	16	103	3	12	-	12	307	12	-	-	319	7.5
2863504	Sterling	-101.1889	32.0722	218ALRS	16	84	3	14	-	14	260	16	-	-	279	7.4
2863505	Sterling	-101.1750	32.0603	218ALRS	15	77	4	12	-	13	245	15	-	-	262	7.6
2863506	Sterling	-101.1725	32.0461	218ALRS	18	80	3	13	-	14	243	13	-	-	267	-
2863602	Sterling	-101.1594	32.0614	218ALRS	17	79	5	18	-	20	244	20	-	-	285	7.5
2863604	Sterling	-101.1478	32.0431	218ALRS	20	117	6	34	-	28	338	45	-	-	436	7.6
2863605	Sterling	-101.1581	32.0431	218ALRS	27	107	9	79	-	69	392	40	-	-	560	7.5
2863606	Sterling	-101.1589	32.0453	218ALRS	21	63	8	95	-	84	151	128	-	-	474	7.2
2863702	Sterling	-101.2097	32.0308	218ALRS	18	104	6	17	-	16	332	22	-	-	347	7.4
2863803	Sterling	-101.1922	32.0175	218ALRS	16	84	2	7	-	8	251	10	-	-	256	7.4
2863804	Sterling	-101.1958	32.0081	218ALRS	12	56	4	25	-	17	201	15	-	-	232	7.5
2863806	Sterling	-101.1725	32.0272	218ALRS	16	83	2	15	-	15	250	15	-	-	272	7.4
2863902	Sterling	-101.1506	32.0308	218ALRS	17	83	5	22	-	23	256	23	-	-	306	7.6
2863903	Sterling	-101.1314	32.0339	218ALRS	17	81	4	21	-	18	253	22	-	-	289	7.4
2864402	Sterling	-101.1092	32.0464	218ALRS	16	76	4	15	-	12	239	16	-	-	259	7.4
2864404	Sterling	-101.1028	32.0492	218ALRS	16	76	4	13	-	11	235	13	-	-	255	7.9
2864502	Sterling	-101.0631	32.0581	218ALRS	23	95	5	30	-	9	350	16	-	-	351	7.5
2864701	Sterling	-101.1014	32.0372	218ALRS	15	80	4	12	-	12	245	16	-	-	262	7.6
2864702	Sterling	-101.0986	32.0117	218ALRS	15	85	3	12	-	13	243	19	-	-	275	7.4
2864704	Sterling	-101.1169	32.0078	218ALRS	15	77	3	6	-	7	233	9	-	-	236	7.6
2864802	Sterling	-101.0808	32.0322	218ALRS	17	100	5	32	-	26	294	36	-	-	385	7.6
2957702	Sterling	-100.9917	32.0203	218ALRS	15	84	4	11	-	11	268	12	-	-	272	7.3
4301101	Sterling	-100.9856	31.9986	218ALRS	16	70	9	16	-	18	239	18	-	-	268	7.7
4301102	Sterling	-100.9944	31.9681	218ALRS	18	56	21	21	-	24	248	25	-	-	295	7.6

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4301303	Sterling	-100.9081	31.9850	218ALRS	10	37	17	61	-	32	262	22	-	-	322	7.7
4301305	Sterling	-100.9042	31.9589	218ALRS	15	43	25	14	-	14	233	19	-	-	252	7.7
4301401	Sterling	-100.9922	31.9506	218ALRS	16	58	19	26	-	31	251	27	-	-	301	7.2
4301402	Sterling	-100.9744	31.9358	218ALRS	17	54	22	21	-	25	240	28	-	-	292	7.6
4301503	Sterling	-100.9494	31.9336	218ALRS	11	46	24	19	-	28	237	20	-	-	275	7.5
4301602	Sterling	-100.9100	31.9361	218ALRS	18	42	26	12	3.5	12	234	13	0.100	0.144	250	7.6
4301603	Sterling	-100.8764	31.9306	218ALRS	1	33	27	26	-	27	163	47	-	-	253	8.8
4301604	Sterling	-100.8758	31.9175	218ALRS	12	42	25	21	-	21	238	18	-	-	266	7.6
4301701	Sterling	-100.9592	31.9000	218ALRS	15	48	23	23	-	23	238	22	-	-	282	7.7
4301702	Sterling	-100.9711	31.9058	218ALRS	17	45	21	9	-	11	227	11	-	-	230	7.5
4301801	Sterling	-100.9517	31.8861	218ALRS	16	53	24	13	-	13	257	16	-	-	270	7.7
4301802	Sterling	-100.9258	31.9086	218ALRS	15	46	25	14	0.3	16	249	15	-	-	264	7.7
4301904	Sterling	-100.9111	31.8972	218ALRS	13	48	21	10	-	11	234	13	-	-	237	7.6
4301905	Sterling	-100.8936	31.9039	218ALRS	17	48	23	12	-	14	237	16	-	-	254	7.8
4301907	Sterling	-100.8764	31.8761	218ALRS	13	51	21	17	-	12	261	12	-	-	260	7.7
4301908	Sterling	-100.8772	31.9031	218ALRS	15	41	23	7	-	9	224	9	-	-	220	7.6
4301911	Sterling	-100.8922	31.9114	218ALRS	-	38	24	11	-	15	232	16	0.089	0.108	248	7.5
4302103	Sterling	-100.8650	31.9719	218ALRS	15	53	31	35	3.2	31	297	35	0.210	0.159	354	7.4
4302104	Sterling	-100.8561	31.9711	218ALRS	16	37	34	41	-	19	293	38	-	-	331	7.5
4302403	Sterling	-100.8353	31.9439	218ALRS	14	61	45	24	-	36	279	77	-	-	409	7.8
4302405	Sterling	-100.8483	31.9494	218ALRS	20	66	52	61	-	61	438	50	-	-	533	8.0
4302706	Sterling	-100.8483	31.9011	218ALRS	14	39	23	19	-	16	224	16	-	-	245	7.6
4302707	Sterling	-100.8689	31.9014	218ALRS	16	37	25	11	0.8	11	216	15	0.079	0.051	231	8.0
4302710	Sterling	-100.8408	31.9025	218ALRS	16	44	23	8	-	12	237	11	-	-	236	7.5
4302711	Sterling	-100.8411	31.8825	218ALRS	15	55	21	6	-	7	260	7	-	-	243	7.6
4302712	Sterling	-100.8414	31.8911	218ALRS	16	45	24	12	-	15	231	16	-	-	253	7.8
4302717	Sterling	-100.8528	31.9067	218ALRS	13	43	25	8	-	14	228	13	-	-	236	7.7
4309107	Sterling	-100.9917	31.8736	218ALRS	22	58	22	14	-	12	282	13	-	-	287	7.8
4309109	Sterling	-100.9600	31.8742	218ALRS	16	53	26	17	-	18	278	17	-	-	290	7.7
4309201	Sterling	-100.9175	31.8683	218ALRS	15	62	22	8	-	9	276	7	-	-	268	7.6
4309203	Sterling	-100.9356	31.8689	218ALRS	15	41	22	23	-	16	235	15	-	-	256	7.7
4309403	Sterling	-100.9886	31.8131	218ALRS	18	56	35	58	-	62	288	73	-	-	446	7.8

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4309504	Sterling	-100.9197	31.8325	218ALRS	18	56	41	37	-	41	345	50	-	-	413	7.9
4309701	Sterling	-100.9783	31.7619	218ALRS	9	63	22	9	-	4	317	18	-	-	282	7.1
4310101	Sterling	-100.8703	31.8481	218ALRS	17	57	23	8	-	8	276	8	-	-	263	7.8
4310103	Sterling	-100.8350	31.8536	218ALRS	20	62	43	10	-	10	381	15	-	-	351	8.3
4310105	Sterling	-100.8561	31.8403	218ALRS	20	73	24	11	-	10	332	7	-	-	322	7.5
4310107	Sterling	-100.8489	31.8581	218ALRS	15	55	21	6	-	7	260	7	-	-	243	7.6
4310402	Sterling	-100.8556	31.8242	218ALRS	18	58	31	17	-	14	321	15	-	-	320	7.6
4310403	Sterling	-100.8375	31.8281	218ALRS	18	83	41	77	-	51	300	165	-	-	590	7.5
4317201	Sterling	-100.9517	31.7467	218ALRS	17	52	27	17	1.6	13	288	15	0.090	0.108	288	7.5
4317202	Sterling	-100.9211	31.7364	218ALRS	19	78	25	25	-	50	311	20	-	-	387	7.5
4317203	Sterling	-100.9256	31.7347	218ALRS	15	66	27	13	-	15	320	17	-	-	314	7.8
4317302	Sterling	-100.8847	31.7303	218ALRS	15	58	26	15	-	18	293	16	-	-	293	7.5
4317303	Sterling	-100.8839	31.7197	218ALRS	16	59	28	14	-	17	303	16	-	-	302	7.7
4317401	Sterling	-100.9869	31.6697	218ALRS	11	42	27	36	-	41	248	21	-	-	316	7.6
4317501	Sterling	-100.9203	31.7069	218ALRS	17	70	27	8	-	10	323	11	-	-	310	7.6
4317503	Sterling	-100.9486	31.6861	218ALRS	23	78	39	29	-	23	422	26	-	-	432	7.8
4317602	Sterling	-100.9083	31.6853	218ALRS	17	61	29	14	-	12	325	14	-	-	312	7.8
4317701	Sterling	-100.9911	31.6544	218ALRS	19	88	16	16	-	12	342	11	-	-	339	7.5
4317803	Sterling	-100.9425	31.6431	218ALRS	10	50	29	14	-	27	262	20	-	-	283	7.6
4317804	Sterling	-100.9444	31.6625	218ALRS	13	51	31	25	-	29	287	19	-	-	320	7.6
4325201	Sterling	-100.9531	31.5925	218ALRS	13	68	10	14	-	18	234	15	-	-	260	7.4
4325301	Sterling	-100.9053	31.6197	218ALRS	-	-	28	16	-	22	270	18	-	-		0.0
4407103	Sterling	-101.2222	31.9719	218ALRS	20	88	13	29	0.2	35	299	39	-	-	382	7.5
4407104	Sterling	-101.2233	31.9708	218ALRS	23	96	19	30	-	30	371	32	-	-	420	7.2
4407201	Sterling	-101.1939	31.9839	218ALRS	16	68	7	26	-	24	231	27	-	-	286	7.7
4407208	Sterling	-101.1811	31.9983	218ALRS	18	82	3	14	-	18	237	20	-	-	283	7.5
4407210	Sterling	-101.1717	31.9783	218ALRS	19	83	7	17	-	19	257	24	-	-	302	7.5
4407212	Sterling	-101.2036	31.9778	218ALRS	-	67	10	21	-	16	251	29	0.154	0.140	308	7.2
4407305	Sterling	-101.1467	31.9819	218ALRS	17	64	12	17	-	20	233	17	-	-	271	7.7
4407504	Sterling	-101.2031	31.9297	218ALRS	27	81	28	19	-	15	367	20	-	-	380	7.4
4407601	Sterling	-101.1308	31.9389	218ALRS	21	57	18	14	-	16	246	17	-	-	271	7.4
4407701	Sterling	-101.2469	31.8956	218ALRS	15	53	23	14	-	15	260	16	-	-	270	7.5

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4407702	Sterling	-101.2286	31.8889	218ALRS	13	48	22	21	-	23	228	23	-	-	274	7.7
4408102	Sterling	-101.0953	31.9706	218ALRS	18	82	5	14	-	12	270	17	-	-	283	7.7
4408201	Sterling	-101.0681	31.9936	218ALRS	11	78	4	5	-	7	239	8	-	-	234	7.7
4408203	Sterling	-101.0631	31.9711	218ALRS	15	82	9	40	-	42	242	58	-	-	366	7.5
4408301	Sterling	-101.0386	31.9953	218ALRS	17	90	4	14	-	18	256	23	-	-	305	7.0
4408303	Sterling	-101.0214	31.9631	218ALRS	18	73	10	9	-	11	248	11	-	-	267	7.6
4408306	Sterling	-101.0325	31.9647	218ALRS	17	84	19	25	-	21	344	24	-	-	368	7.5
4408401	Sterling	-101.0872	31.9522	218ALRS	27	112	8	32	-	29	367	31	-	-	423	7.4
4408501	Sterling	-101.0539	31.9289	218ALRS	20	70	18	35	-	32	279	40	-	-	357	7.6
4408502	Sterling	-101.0478	31.9172	218ALRS	17	67	14	22	-	20	267	21	-	-	297	7.4
4408503	Sterling	-101.0625	31.9303	218ALRS	24	145	41	125	-	137	294	263	-	-	913	7.4
4408504	Sterling	-101.0686	31.9411	218ALRS	20	70	8	21	-	17	243	19	-	-	284	7.7
4408601	Sterling	-101.0356	31.9311	218ALRS	21	110	18	38	-	37	336	38	-	-	499	7.5
4408602	Sterling	-101.0333	31.9475	218ALRS	15	73	12	23	-	16	281	21	-	-	302	7.5
4408901	Sterling	-101.0028	31.8922	218ALRS	28	78	18	9	-	7	311	7	-	-	312	7.5
4414601	Sterling	-101.2575	31.8017	218ALRS	22	84	47	72	2.0	125	329	112	-	-	641	7.7
4415203	Sterling	-101.1933	31.8503	218ALRS	16	55	21	13	-	16	254	21	-	-	268	7.2
4415205	Sterling	-101.1728	31.8436	218ALRS	15	52	21	18	-	18	253	17	-	-	273	7.3
4415206	Sterling	-101.1681	31.8394	218ALRS	17	62	23	16	0.1	18	283	16	-	-	303	7.6
4415302	Sterling	-101.1511	31.8547	218ALRS	12	48	19	14	-	18	226	18	-	-	249	7.6
4415506	Sterling	-101.1808	31.8119	218ALRS	-	90	63	103	-	136	325	160	-	-	727	7.6
4415507	Sterling	-101.1728	31.8219	218ALRS	-	167	89	153	-	220	323	316	-	-	1,122	6.8
4415603	Sterling	-101.1372	31.8050	218ALRS	-	86	20	14	5.0	25	346	29	-	-	356	7.3
4415604	Sterling	-101.1272	31.8081	218ALRS	17	113	40	34	-	17	354	147	-	0.100	557	7.3
4415605	Sterling	-101.1564	31.8139	218ALRS	-	543	175	2,503	5.0	167	233	4,288	-	-	7,806	8.1
4415608	Sterling	-101.1631	31.8067	218ALRS	18	168	73	599	3.2	67	300	1,293	3.870	0.096	2,379	7.2
4415609	Sterling	-101.1658	31.8086	218ALRS	15	130	82	1,154	5.5	110	287	2,000	-	-	3,643	7.0
4415610	Sterling	-101.1658	31.8083	218ALRS	-	1,203	486	8,644	-	543	244	16,330	-	-	27,325	7.6
4415611	Sterling	-101.1528	31.8108	218ALRS	-	159	95	638	6.0	158	244	1,214	-	-	2,401	7.9
4415612	Sterling	-101.1578	31.8142	218ALRS	-	343	5	323	26.0	251	131	527	-	-	1,600	7.6
4415613	Sterling	-101.1581	31.8203	218ALRS	-	41	29	29	5.0	299	299	23	-	-	580	8.0
4415614	Sterling	-101.1567	31.8150	218ALRS	-	48	56	97	5.0	237	237	117	-	-	684	7.1

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4415615	Sterling	-101.1547	31.8164	218ALRS	-	55	31	50	-	58	201	45	-	-	349	6.8
4415616	Sterling	-101.1622	31.8106	218ALRS	-	244	165	10,540	29.0	415	292	14,485	-	-	26,035	7.5
4415618	Sterling	-101.1625	31.8289	218ALRS	-	170	103	180	-	238	326	399	-	-	1,267	7.3
4415619	Sterling	-101.1478	31.8331	218ALRS	-	131	88	94	-	80	356	306	-	-	887	7.4
4415620	Sterling	-101.1661	31.8111	218ALRS	-	203	125	106	-	86	395	495	-	-	1,220	6.4
4415621	Sterling	-101.1653	31.8014	218ALRS	-	116	43	17	-	10	420	58	-	-	458	6.7
4415623	Sterling	-101.1389	31.8050	218ALRS	-	212	50	364	5.0	54	331	763	-	-	1,621	6.7
4415702	Sterling	-101.2231	31.7764	218ALRS	16	62	19	11	-	14	270	15	-	-	278	7.6
4415704	Sterling	-101.2336	31.7544	218ALRS	14	42	29	36	3.0	56	222	33	-	-	346	8.3
4415801	Sterling	-101.1739	31.7906	218ALRS	-	52	20	26	5.0	10	219	39	-	-	267	7.9
4415804	Sterling	-101.1683	31.7622	218ALRS	13	45	25	13	-	16	239	15	-	-	252	7.5
4415901	Sterling	-101.1531	31.7847	218ALRS	-	46	26	11	5.0	13	234	14	-	-	238	7.9
4415902	Sterling	-101.1556	31.7681	218ALRS	17	57	23	12	-	12	277	13	-	-	280	7.7
4415903	Sterling	-101.1408	31.7556	218ALRS	16	49	26	14	-	19	253	20	-	-	275	7.7
4416108	Sterling	-101.1161	31.8647	218ALRS	16	49	22	13	1.1	16	238	13	-	0.078	258	7.5
4416403	Sterling	-101.1247	31.8050	218ALRS	13	51	21	9	-	12	244	13	-	0.100	244	7.6
4416405	Sterling	-101.0856	31.8244	218ALRS	18	63	29	13	-	17	309	21	-	-	317	7.6
4416608	Sterling	-101.0144	31.8072	218ALRS	15	62	26	13	-	14	299	17	-	-	295	7.4
4416609	Sterling	-101.0103	31.8047	218ALRS	21	234	143	198	-	399	260	690	-	-	1,829	7.5
4416615	Sterling	-101.0233	31.7922	218ALRS	-	62	29	9	-	14	310	13	0.108	0.120	328	7.6
4416701	Sterling	-101.1236	31.7669	218ALRS	15	44	27	12	-	15	246	17	-	-	256	7.6
4416901	Sterling	-101.0228	31.7803	218ALRS	18	53	27	19	-	17	298	17	-	-	302	7.6
4416902	Sterling	-101.0386	31.7686	218ALRS	23	109	54	74	0.2	84	453	138	-	-	707	7.6
4424101	Sterling	-101.0958	31.7178	218ALRS	28	81	32	25	-	32	381	22	-	-	418	6.7
4424102	Sterling	-101.0903	31.7331	218ALRS	15	72	23	14	-	12	331	12	-	-	316	7.6
4424301	Sterling	-101.0042	31.7256	218ALRS	18	59	33	29	-	30	334	31	-	-	372	7.5
4424503	Sterling	-101.0642	31.6964	218ALRS	23	84	31	21	1.6	19	355	31	-	-	398	7.4
4424602	Sterling	-101.0069	31.7064	218ALRS	10	56	25	17	-	12	292	20	-	-	284	7.4
4326702	Tom Green	-100.8444	31.5303	218ALRS	10	50	26.5	29.8	-	67	275	12	0.065	0.128	339	7.9
4351304	Tom Green	-100.6489	31.2367	218ALRS	28	116	31	22	0.8	18	453	36	0.230	0.113	482	7.6
4352401	Tom Green	-100.6019	31.1864	218ALRS	22	65.4	23.5	15	2.3	13	282	23	0.060	0.079	317	7.7

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2937708	Nolan	-100.4628	32.3783	218ALRS	20	317	104	37	3.1	1,050	190	17	0.105	0.050	1,657	7.0
2937801	Nolan	-100.4550	32.3775	218ALRS	18	325	66	162	-	907	305	162	-	-	1,823	7.9
2944519	Nolan	-100.5753	32.3250	218ALRS	19	93	7	97	1.6	96	267	65	0.655	0.334	575	7.4
2944605	Nolan	-100.5361	32.3083	218ALRS	15	83	5	17	1.1	20	244	13	0.140	0.150	293	7.2
2945204	Nolan	-100.4564	32.3744	218ALRS	24	89	10	77	1.9	71	342	46	0.190	0.190	494	7.0
2945704	Nolan	-100.4906	32.2697	218ALRS	18	102	8	33	2.0	40	288	50	-	-	415	8.1
2947605	Nolan	-100.1661	32.2964	218ALRS	14	58	27	28	3.0	51	294	25	0.106	0.129	361	7.2
2947901	Nolan	-100.1497	32.2592	218ALRS	8	58	27	31	-	46	312	13	-	-	338	7.8
2951903	Nolan	-100.6364	32.1614	218ALRS	13	99	30	36	-	99	344	44	-	-	490	7.0
2952104	Nolan	-100.6156	32.2256	218ALRS	12	79	7	14	-	30	242	15	-	0.300	277	7.4
2952312	Nolan	-100.5383	32.2092	218ALRS	12	66	17	17	2.0	38	250	22	-	0.340	305	8.1
2952602	Nolan	-100.5703	32.1675	218ALRS	15	71	15	6	0.8	10	261	9	0.030	0.059	261	7.4
2952803	Nolan	-100.5583	32.1469	218ALRS	11	85	20	17	-	69	292	21	-	-	368	8.1
2952807	Nolan	-100.5806	32.1294	218ALRS	13	69	15	20	-	29	260	23	-	0.280	298	7.3
2953103	Nolan	-100.4769	32.2350	218ALRS	21	112	15	92	2.5	65	284	138	-	-	621	7.1
2953104	Nolan	-100.4744	32.2442	218ALRS	21	152	17	138	-	129	248	276	-	-	872	7.7
2953106	Nolan	-100.4861	32.2428	218ALRS	19	115	17	59	2.2	76	287	115	0.790	0.167	557	7.1
2953205	Nolan	-100.4572	32.2344	218ALRS	19	72	14	24	2.6	26	267	38	0.143	0.127	337	7.1
2953302	Nolan	-100.4092	32.2133	218ALRS	13	91	4	6	-	15	270	9	-	-	283	8.3
2953702	Nolan	-100.4722	32.1494	218ALRS	12	53	21	6	-	9	256	7	-	-	235	7.9
2954201	Nolan	-100.3219	32.2281	218ALRS	15	94	17	13	0.8	46	331	14	0.112	0.082	373	7.1
2954502	Nolan	-100.3267	32.2028	218ALRS	20	119	21	113	-	121	355	147	-	-	716	7.7
2955401	Nolan	-100.2350	32.1950	218ALRS	12	72	31	15	3.6	50	314	11	-	-	356	7.2
2960202	Nolan	-100.5531	32.0861	218ALRS	12	63	36	8	-	21	351	11	-	0.190	324	8.0
2960301	Nolan	-100.5319	32.1208	218ALRS	18	360	148	337	7.0	1,493	288	291	-	0.250	2,836	7.5
2864804	Sterling	-101.0442	32.0275	218ASDG	20	78	4	15	1.0	15	237	15	0.070	0.068	274	7.1
2864804	Sterling	-101.0442	32.0275	218ASDG	20	68	4	14	1.0	12	239	13	0.078	0.088	257	7.1
4415508	Sterling	-101.1958	31.8175	218ASDG	26	187	83	256	3.8	179	278	722	-	0.312	1,573	6.9
4343905	Tom Green	-100.6339	31.2819	218CMPK	-	84.4	25.5	50.3	-	48	319	78	0.317	0.204	481	7.1
4353106	Tom Green	-100.4906	31.2347	218CMPK	-	86	17.9	122	-	28	299	206	0.489	0.146	633	7.2

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4353801	Tom Green	-100.4325	31.1481	218CMPK	16	78	15.4	8.36	1.3	12	281	13	0.070	0.049	292	7.9
4354202	Tom Green	-100.2964	31.2308	218CMPK	19	61	22.7	9.67	1.0	24	254	15	0.070	0.077	287	7.6
4424804	Sterling	-101.0547	31.6525	218EDAS	-	43	24	12	-	11	253	12	0.105	0.118	253	7.5
4424802	Sterling	-101.0714	31.6408	218EDDT	14	39	28	18	1.5	24	220	23	0.130	0.143	268	7.6
4301302	Sterling	-100.8819	31.9756	218EDRDA	22	104	25	18	-	42	342	34	-	-	437	7.7
4301501	Sterling	-100.9233	31.9283	218EDRDA	23	50	19	18	4.0	19	226	27	-	-	284	7.5
4423201	Sterling	-101.1914	31.7347	218EDRDA	27	53	35	37	-	67	229	59	-	-	417	7.6
4423202	Sterling	-101.2042	31.7147	218EDRDA	15	49	28	29	-	45	246	29	-	-	332	7.7
4423203	Sterling	-101.1694	31.7239	218EDRDA	12	44	29	26	-	37	232	30	-	-	310	7.7
4423401	Sterling	-101.2117	31.6972	218EDRDA	17	68	27	19	-	23	315	27	-	-	337	7.5
4423501	Sterling	-101.1722	31.6758	218EDRDA	12	44	26	20	-	30	227	25	-	-	282	7.8
4423502	Sterling	-101.1925	31.6808	218EDRDA	25	100	36	20	0.2	23	465	26	-	-	470	8.0
4423601	Sterling	-101.1506	31.6753	218EDRDA	15	73	16	25	-	33	260	30	-	-	333	7.6
4423801	Sterling	-101.1828	31.6281	218EDRDA	17	41	28	19	0.3	25	229	23	-	-	281	7.5
4423802	Sterling	-101.2047	31.6386	218EDRDA	15	45	25	17	-	25	228	20	-	-	272	8.1
4423901	Sterling	-101.1336	31.6297	218EDRDA	16	44	23	20	-	23	226	26	-	-	273	7.6
4432103	Sterling	-101.0872	31.6139	218EDRDA	15	58	16	17	-	19	205	30	-	-	271	7.7
4353714	Tom Green	-100.4925	31.1561	218EDRDA	17	95	20.9	26.3	1.8	13	343	42	0.164	0.050	398	6.8
4302804	Coke	-100.7947	31.9044	218FKBT	18	49	30	15	3.5	21	250	36	0.162	0.121	310	7.4
4310603	Coke	-100.7831	31.8319	218FKBT	19	82	22	8	1.0	14	342	9	0.068	-	334	7.2
4311501	Coke	-100.6803	31.8083	218FKBT	20	62	25	50	2.2	41	264	74	0.240	0.196	414	7.6
4311607	Coke	-100.6308	31.8083	218FKBT	16	67	35	75	3.4	57	276	84	0.350	0.235	508	7.2
4312406	Coke	-100.6128	31.8197	218FKBT	16	98	47	33	4.4	77	427	40	0.330	0.250	529	7.5
4319104	Coke	-100.7228	31.7156	218FKBT	20	66	41	35	2.1	34	325	68	0.150	0.187	444	7.5
4321507	Coke	-100.4542	31.6958	218FKBT	18	59	28	19	3.6	33	305	21	0.101	0.129	363	7.3
2828805	Howard	-101.5653	32.5142	231DCKM	27	146	56	187	7.4	157	231	449	2.430	0.412	1,262	7.4
2829703	Howard	-101.4922	32.5072	231DCKM	-	102	14	58	-	65	268	102	-	-	472	-
2829704	Howard	-101.4958	32.5178	231DCKM	-	81	28	215	-	204	342	210	-	-	906	-
2830901	Howard	-101.2800	32.5178	231DCKM	60	178	263	526	10.0	2,054	301	219	-	-	3,458	8.0
2830903	Howard	-101.2708	32.5050	231DCKM	-	196	78	126	-	753	305	38	-	-	1,340	-
2838101	Howard	-101.3614	32.4764	231DCKM	-	75	32	624	-	868	153	460	-	-	2,134	-

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2838102	Howard	-101.3531	32.4981	231DCKM	12	55	16	1,949	7.0	1,764	531	1,593	-	-	5,658	8.1
2838103	Howard	-101.3531	32.4981	231DCKM	11	33	15	1,840	10.0	1,501	603	1,379	0.110	1.220	5,089	7.8
2838302	Howard	-101.2572	32.4592	231DCKM	-	61	21	76	-	117	293	30	-	-	449	-
2838303	Howard	-101.2697	32.4847	231DCKM	-	128	116	1,130	-	2,269	311	455	-	-	4,250	-
2838601	Howard	-101.2786	32.4175	231DCKM	10	63	25	1,358	9.4	978	399	1,285	6.200	1.487	3,928	7.3
2838602	Howard	-101.2525	32.4458	231DCKM	-	17	21	1,130	-	787	380	1,030	-	-	3,171	-
2838604	Howard	-101.2697	32.4231	231DCKM	-	48	25	1,300	-	905	452	1,240	-	-	3,740	-
2839101	Howard	-101.2294	32.4667	231DCKM	51	140	63	148	3.4	306	229	200	1.640	0.750	1,223	7.3
2839102	Howard	-101.2283	32.4664	231DCKM	-	17	17	1,176	-	603	690	1,050	-	-	3,202	-
2839105	Howard	-101.2250	32.4967	231DCKM	-	22	24	1,140	-	699	659	970	-	-	3,179	-
2839107	Howard	-101.2358	32.4806	231DCKM	-	38	66	187	-	205	482	116	-	-	848	-
2839203	Howard	-101.2003	32.4806	231DCKM	-	1	36	1,385	-	783	696	1,260	-	-	3,807	-
2839401	Howard	-101.2256	32.4244	231DCKM	11	32	10	992	5.0	698	483	837	-	-	2,832	8.5
2839402	Howard	-101.2383	32.4189	231DCKM	11	37	18	1,380	9.1	893	502	1,157	0.230	1.470	3,754	7.6
2839404	Howard	-101.2331	32.4214	231DCKM	-	37	19	1,355	-	952	494	1,220	-	-	3,825	0.0
2839408	Howard	-101.2386	32.4511	231DCKM	-	54	1	1,150	-	653	549	1,070	-	-	3,197	0.0
2846801	Howard	-101.3094	32.2767	231DCKM	13	35	20	469	7.2	287	287	422	1.800	2.025	1,399	7.6
2846802	Howard	-101.3094	32.2764	231DCKM	91	69	25	266	5.9	224	312	262	1.600	1.030	1,183	7.0
2831901	Mitchell	-101.1392	32.5214	231DCKM	15	112	141	2,240	-	998	292	3,150	-	-	6,799	-
2832704	Mitchell	-101.1156	32.5028	231DCKM	6	129	70	2,350	-	1,420	382	2,780	-	-	6,942	-
2832705	Mitchell	-101.0844	32.5206	231DCKM	23	82	59	305	-	312	427	154	-	-	1,378	7.8
2832801	Mitchell	-101.0544	32.5253	231DCKM	19	66	38	89	-	201	140	122	-	-	619	-
2832901	Mitchell	-101.0008	32.5139	231DCKM	23	259	192	311	-	1,670	232	130	-	-	2,700	-
2839801	Mitchell	-101.1683	32.4139	231DCKM	11	79	46	1,560	-	1,160	423	1,630	-	-	4,695	8.1
2839802	Mitchell	-101.1683	32.4139	231DCKM	60	56	23	267	-	319	382	79	-	-	1,055	8.0
2839803	Mitchell	-101.1683	32.4139	231DCKM	20	148	75	964	-	885	329	1,150	-	-	3,406	8.2
2840101	Mitchell	-101.0883	32.4939	231DCKM	5	169	88	2,820	-	1,650	290	3,510	-	-	8,384	-
2840102	Mitchell	-101.1086	32.4897	231DCKM	7	129	64	2,190	-	1,390	325	2,540	-	-	6,509	-
2840301	Mitchell	-101.0336	32.4811	231DCKM	10	9	7	715	-	463	499	480	-	-	1,953	-
2840312*	Mitchell	-101.0053	32.4969	231DCKM	17	340	330	330	10.0	2,500	-	150	2.700	0.240	3830	7.3
2840401	Mitchell	-101.1200	32.4286	231DCKM	11	105	26	1,520	-	1,990	448	890	-	-	4,764	7.9
2840601	Mitchell	-101.0344	32.4542	231DCKM	4	13	9	952	-	454	516	850	-	-	2,563	-

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2840602*	Mitchell	-101.0103	32.4217	231DCKM	13	210	280	360	8.2	1,600	-	460	2.000	0.310	3090	7.4
2840603	Mitchell	-101.0114	32.4408	231DCKM	7	214	249	446	-	1,760	460	225	-	-	3,127	-
2840607	Mitchell	-101.0111	32.4417	231DCKM	12	154	208	349	7.2	1,440	480	120	1.000	0.597	2,543	7.1
2840608	Mitchell	-101.0317	32.4531	231DCKM	7	9	4	694	3.0	386	545	519	-	-	1,893	8.0
2840609	Mitchell	-101.0361	32.4358	231DCKM	10	338	133	5,779	18.0	2,777	358	7,774	-	-	17,007	7.9
2840713	Mitchell	-101.1053	32.3897	231DCKM	11	77	33	1,540	-	1,300	359	1,500	-	-	4,639	7.5
2840718	Mitchell	-101.0839	32.3817	231DCKM	10	113	66	2,800	6.0	2,044	405	2,912	-	-	8,151	8.3
2840803	Mitchell	-101.0817	32.3997	231DCKM	10	114	82	2,140	-	2,030	282	2,240	-	-	6,756	7.9
2840806	Mitchell	-101.0711	32.3772	231DCKM	8	93	41	2,420	-	2,030	389	2,310	-	-	7,097	7.8
2840811	Mitchell	-101.0806	32.3925	231DCKM	19	60	47	372	3.4	257	376	349	-	-	1,361	8.0
2840905	Mitchell	-101.0372	32.3783	231DCKM	10	86	37	2,396	9.0	1,932	428	2,240	-	-	6,921	8.1
2847604	Mitchell	-101.1461	32.3117	231DCKM	45	720	416	530	-	250	305	3,040	-	-	5,163	7.5
2848302	Mitchell	-101.0178	32.3569	231DCKM	15	79	66	159	-	430	345	62	-	-	986	8.0
2848601	Mitchell	-101.0028	32.3219	231DCKM	27	99	74	1,540	-	1,590	273	1,520	-	-	4,987	7.6
2848602	Mitchell	-101.0100	32.3036	231DCKM	24	218	377	1,150	-	3,170	514	570	-	-	5,832	7.6
2848608	Mitchell	-101.0403	32.2953	231DCKM	14	341	145	620	-	1,630	244	650	-	-	3,543	7.6
2848609	Mitchell	-101.0250	32.2975	231DCKM	10	11	9	410	3.3	325	334	217	1.140	0.987	1,155	8.2
2848901*	Mitchell	-101.0092	32.2758	231DCKM	13	46	79	1,400	3.0	1,400	-	1,000	4.800	2.600	4,230	7.9
2925702	Mitchell	-100.9994	32.5178	231DCKM	10	184	93	214	-	914	184	145	-	-	1,651	-
2925703	Mitchell	-100.9858	32.5161	231DCKM	12	356	65	149	-	1,190	94	112	-	-	1,938	-
2925706	Mitchell	-100.9853	32.5139	231DCKM	16	118	39	141	-	510	226	44	-	-	1,002	7.9
2925801	Mitchell	-100.9403	32.5150	231DCKM	29	491	102	60	-	1,500	128	54	-	-	2,303	7.5
2925903	Mitchell	-100.9133	32.5064	231DCKM	19	86	31	58	-	173	257	60	-	0.170	557	7.9
2926702	Mitchell	-100.8603	32.5047	231DCKM	18	152	26	104	-	180	257	192	-	0.370	867	7.3
2926801	Mitchell	-100.8033	32.5233	231DCKM	18	97	32	97	-	159	243	146	-	-	671	7.2
2926903	Mitchell	-100.7836	32.5153	231DCKM	23	91	14	98	2.0	95	233	108	-	0.430	632	7.4
2926907	Mitchell	-100.7547	32.5200	231DCKM	8	56	29	738	-	1,053	250	390	-	2.100	2,398	8.1
2927902	Mitchell	-100.6622	32.5147	231DCKM	49	152	155	252	9.0	420	326	538	-	-	1,850	7.6
2933101	Mitchell	-100.9867	32.4978	231DCKM	20	180	40	194	3.5	411	233	150	1.490	0.493	1,355	7.1
2933102	Mitchell	-100.9931	32.4944	231DCKM	16	52	34	96	-	178	227	56	-	-	569	-
2933103	Mitchell	-100.9681	32.4942	231DCKM	20	56	28	80	-	135	124	126	-	-	514	-
2933105	Mitchell	-100.9994	32.4619	231DCKM	18	102	78	310	4.0	535	299	283	-	-	1,586	8.3

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2933108	Mitchell	-100.9819	32.4672	231DCKM	15	277	200	660	-	1,970	270	520	-	-	3,798	7.8
2933110	Mitchell	-100.9589	32.4594	231DCKM	6	34	10	187	-	111	392	23	-	-	608	-
2933201	Mitchell	-100.9469	32.4933	231DCKM	14	44	98	214	-	510	228	170	-	-	1,188	-
2933202*	Mitchell	-100.9233	32.4800	231DCKM	<1	230	130	170	14.0	280	-	760	2.400	0.100	1640	6.4
2933203	Mitchell	-100.9494	32.4753	231DCKM	12	622	496	910	-	3,980	85	960	-	-	7,024	-
2933206	Mitchell	-100.9347	32.4650	231DCKM	48	378	154	377	-	1,730	275	250	-	0.630	3,073	7.5
2933207	Mitchell	-100.9258	32.4822	231DCKM	12	483	261	1,910	-	2,000	293	3,090	-	-	7,901	7.5
2933306	Mitchell	-100.9044	32.4850	231DCKM	19	107	23	53	-	134	328	43	-	0.280	569	7.9
2933401	Mitchell	-100.9767	32.4247	231DCKM	20	57	25	259	-	180	189	290	-	-	984	-
2933404	Mitchell	-100.9917	32.4219	231DCKM	7	96	21	171	-	313	300	52	-	-	871	-
2933405	Mitchell	-100.9892	32.4325	231DCKM	20	62	36	137	-	102	158	228	-	-	712	-
2933407	Mitchell	-100.9769	32.4569	231DCKM	16	34	5	157	-	93	310	25	-	-	567	8.4
2933501	Mitchell	-100.9508	32.4464	231DCKM	9	410	111	282	-	1,390	116	390	-	-	2,649	0.0
2933601	Mitchell	-100.8911	32.4244	231DCKM	17	93	54	255	-	466	343	178	-	0.620	1,232	7.9
2933701	Mitchell	-100.9739	32.4106	231DCKM	27	131	49	188	-	263	283	242	-	-	1,172	7.3
2933806	Mitchell	-100.9439	32.4003	231DCKM	13	186	104	120	-	860	143	69	-	-	1,441	7.8
2933902	Mitchell	-100.9114	32.4031	231DCKM	-	192	62	108	-	406	292	217	-	-	1,128	-
2933906	Mitchell	-100.8800	32.4000	231DCKM	15	72	34	171	-	276	312	104	-	-	827	7.7
2933907	Mitchell	-100.8836	32.3958	231DCKM	13	58	26	175	-	206	317	103	-	0.510	738	7.9
2933908	Mitchell	-100.9014	32.3819	231DCKM	14	200	62	620	-	520	267	930	-	0.340	2,489	7.3
2933910	Mitchell	-100.8906	32.3992	231DCKM	14	150	75	810	-	550	306	1,120	-	0.630	2,871	7.8
2933914	Mitchell	-100.8986	32.3814	231DCKM	21	82	13	72	1.8	109	217	58	0.550	0.218	542	7.0
2933915	Mitchell	-100.9111	32.4022	231DCKM	42	201	84	1,220	-	1,020	305	1,560	-	-	4,278	7.9
2933917	Mitchell	-100.8783	32.4100	231DCKM	15	51	32	136	4.4	192	326	59	-	0.460	653	7.5
2934106	Mitchell	-100.8678	32.4600	231DCKM	14	55	76	301	-	610	317	154	-	1.100	1,368	7.9
2934207	Mitchell	-100.8142	32.4583	231DCKM	17	209	182	377	-	750	412	670	-	1.200	2,431	7.6
2934209	Mitchell	-100.8003	32.4700	231DCKM	15	60	52	120	-	219	348	77	-	0.550	721	7.6
2934301	Mitchell	-100.7842	32.4744	231DCKM	28	94	48	119	-	270	339	87	-	0.430	813	7.4
2934302	Mitchell	-100.7536	32.4603	231DCKM	22	119	76	139	-	227	359	268	-	0.660	1,054	7.4
2934401	Mitchell	-100.8669	32.4194	231DCKM	14	43	34	139	3.4	198	328	49	-	0.680	643	7.7
2934403	Mitchell	-100.8586	32.4250	231DCKM	-	61	45	117	-	190	328	88	-	-	662	-
2934405	Mitchell	-100.8531	32.4342	231DCKM	-	46	32	133	-	165	342	50	-	-	594	-

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2934413	Mitchell	-100.8617	32.4414	231DCKM	16	52	36	173	-	260	333	67	-	0.580	769	7.8
2934414	Mitchell	-100.8503	32.4478	231DCKM	28	77	75	366	-	475	377	323	-	0.950	1,554	7.9
2934428	Mitchell	-100.8539	32.4261	231DCKM	37	67	24	160	2.0	202	243	130	-	-	781	8.3
2934501	Mitchell	-100.8175	32.4272	231DCKM	22	117	81	97	4.5	464	310	69	0.400	0.490	1,014	7.2
2934503	Mitchell	-100.8128	32.4331	231DCKM	19	119	59	96	-	357	320	85	-	-	893	8.1
2934505	Mitchell	-100.8072	32.4572	231DCKM	22	60	40	84	-	164	325	42	-	0.430	573	7.4
2934509	Mitchell	-100.8278	32.4278	231DCKM	-	96	60	101	-	320	342	70	-	-	815	7.4
2934512	Mitchell	-100.8239	32.4283	231DCKM	-	80	73	254	-	320	756	70	-	-	1,168	7.0
2934515	Mitchell	-100.8319	32.4544	231DCKM	18	67	45	128	-	187	294	108	-	0.550	765	7.5
2934523	Mitchell	-100.8214	32.4519	231DCKM	19	54	35	101	6.0	169	319	41	-	0.050	585	7.5
2934524	Mitchell	-100.8047	32.4286	231DCKM	21	108	67	105	6.0	380	203	142	-	-	940	8.1
2934701	Mitchell	-100.8653	32.4100	231DCKM	15	58	35	112	5.6	227	281	46	-	-	638	8.0
2934702	Mitchell	-100.8481	32.3994	231DCKM	-	196	91	91	-	696	316	55	-	-	1,284	-
2934703	Mitchell	-100.8386	32.3839	231DCKM	-	187	62	37	-	455	316	50	-	-	946	-
2934706	Mitchell	-100.8647	32.3817	231DCKM	15	118	63	405	-	510	397	428	-	0.820	1,735	7.6
2934708	Mitchell	-100.8644	32.4056	231DCKM	-	141	68	78	-	433	324	61	-	-	940	-
2934709	Mitchell	-100.8669	32.4136	231DCKM	-	61	37	105	-	208	304	47	-	-	607	-
2934714	Mitchell	-100.8689	32.4122	231DCKM	16	59	54	107	-	301	259	43	-	0.470	709	8.0
2934721	Mitchell	-100.8753	32.4092	231DCKM	22	133	65	131	4.0	570	200	86	-	-	1,110	8.3
2934724	Mitchell	-100.8364	32.3786	231DCKM	22	242	104	107	5.3	621	333	180	0.550	0.353	1,468	7.1
2934801	Mitchell	-100.8278	32.4081	231DCKM	-	126	62	69	-	393	310	40	-	-	842	-
2934802	Mitchell	-100.8094	32.4150	231DCKM	-	205	51	28	-	396	266	52	-	-	960	-
2934803	Mitchell	-100.7989	32.4033	231DCKM	16	82	42	54	-	193	314	35	-	0.490	577	8.0
2934804	Mitchell	-100.7983	32.4031	231DCKM	18	226	97	73	-	689	325	105	-	-	1,368	7.6
2934805	Mitchell	-100.8050	32.3819	231DCKM	18	2	1	447	-	490	417	91	-	-	1,272	8.5
2934905	Mitchell	-100.7781	32.4061	231DCKM	18	66	35	35	-	70	310	36	-	-	413	7.6
2934906	Mitchell	-100.7544	32.3969	231DCKM	17	79	36	32	-	84	328	38	-	-	449	7.7
2934908	Mitchell	-100.7669	32.3900	231DCKM	18	74	41	56	-	122	310	63	-	0.290	527	7.6
2935108	Mitchell	-100.7447	32.4992	231DCKM	18	184	19	121	-	115	204	186	-	0.300	1,064	7.3
2935202	Mitchell	-100.6833	32.4611	231DCKM	18	81	43	60	-	163	353	35	-	0.400	576	8.2
2935208	Mitchell	-100.7067	32.4922	231DCKM	12	110	53	281	11.0	410	290	277	-	-	1,354	7.0
2935321	Mitchell	-100.6619	32.4697	231DCKM	18	79	40	103	8.0	176	259	128	-	-	688	8.1

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2935401	Mitchell	-100.7189	32.4308	231DCKM	18	63	28	42	-	60	307	27	-	0.270	392	8.1
2935406	Mitchell	-100.7169	32.4522	231DCKM	15	74	33	46	-	115	319	29	-	0.440	471	8.0
2935416	Mitchell	-100.7211	32.4289	231DCKM	16	68	33	41	-	78	321	31	-	0.350	427	7.6
2935504	Mitchell	-100.6864	32.4222	231DCKM	14	64	29	45	-	62	321	32	-	0.420	406	7.7
2935507	Mitchell	-100.6781	32.4556	231DCKM	-	66	42	52	-	180	263	30	-	-	499	8.5
2935701	Mitchell	-100.7125	32.4036	231DCKM	-	74	31	48	0.5	97	299	50	-	-	452	-
2935702	Mitchell	-100.7125	32.4036	231DCKM	17	72	25	41	2.7	74	288	38	0.101	0.230	414	7.2
2935703	Mitchell	-100.7131	32.4033	231DCKM	-	92	28	33	-	120	299	36	-	-	458	0.0
2935708	Mitchell	-100.7342	32.4142	231DCKM	14	66	30	45	-	66	320	34	-	0.210	413	8.1
2935712	Mitchell	-100.7417	32.3853	231DCKM	13	58	50	193	-	274	317	151	-	0.750	920	8.0
2935719	Mitchell	-100.7125	32.3847	231DCKM	21	183	79	131	-	443	309	238	-	-	1,254	8.0
2935801	Mitchell	-100.6728	32.4122	231DCKM	17	53	24	31	-	38	260	27	-	0.340	320	7.7
2935802	Mitchell	-100.6883	32.3942	231DCKM	36	62	24	27	-	36	264	39	-	0.320	355	7.9
2935811	Mitchell	-100.6836	32.3894	231DCKM	34	111	39	125	3.0	259	411	64	-	0.590	878	6.9
2941103	Mitchell	-100.9728	32.3428	231DCKM	13	24	14	475	5.0	521	449	183	-	-	1,466	8.5
2941104	Mitchell	-100.9692	32.3531	231DCKM	11	170	52	186	-	670	359	53	-	-	1,320	7.9
2941304	Mitchell	-100.9028	32.3625	231DCKM	22	112	49	220	-	129	222	218	-	0.410	1,322	7.3
2941307	Mitchell	-100.8961	32.3569	231DCKM	16	491	165	616	-	1,075	282	1,327	-	-	3,891	8.0
2941401	Mitchell	-100.9606	32.3183	231DCKM	26	68	24	260	-	292	331	148	-	-	1,060	8.1
2941403	Mitchell	-100.9931	32.3039	231DCKM	52	57	48	306	-	507	333	125	-	0.900	1,293	8.2
2941501	Mitchell	-100.9400	32.3028	231DCKM	36	78	37	141	-	251	272	136	-	-	817	7.7
2941701	Mitchell	-100.9672	32.2706	231DCKM	8	436	258	2,710	-	3,226	121	3,158	-	-	9,860	7.7
2941702	Mitchell	-100.9864	32.2589	231DCKM	14	228	178	497	-	1,630	311	331	-	-	3,032	8.0
2941705*	Mitchell	-100.9861	32.2586	231DCKM	18	490	760	2,000	32.0	4,700	-	2,700	14.000	1.600	10900	7.3
2942101	Mitchell	-100.8344	32.3639	231DCKM	-	163	82	68	-	507	334	36	-	-	1,044	-
2942102	Mitchell	-100.8625	32.3458	231DCKM	22	132	65	63	-	432	273	31	-	0.400	880	7.9
2942205	Mitchell	-100.8128	32.3672	231DCKM	-	122	89	149	-	367	320	209	-	-	1,150	-
2942208	Mitchell	-100.8286	32.3472	231DCKM	27	615	344	114	-	2,520	478	150	-	-	4,006	8.0
2942209	Mitchell	-100.8144	32.3336	231DCKM	21	402	94	72	-	1,260	183	51	-	0.540	2,028	7.3
2942213	Mitchell	-100.8100	32.3439	231DCKM	23	164	68	101	5.0	504	245	108	-	-	1,111	8.1
2942216	Mitchell	-100.8192	32.3528	231DCKM	18	163	77	76	7.3	507	320	65	-	0.420	1,075	7.1
2942301	Mitchell	-100.7544	32.3467	231DCKM	18	90	39	34	-	118	304	57	-	0.180	506	7.5

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2942302	Mitchell	-100.7550	32.3503	231DCKM	16	84	31	41	3.5	127	288	49	-	0.160	493	7.1
2942304	Mitchell	-100.7906	32.3589	231DCKM	39	92	58	97	-	274	309	99	-	0.560	817	7.3
2942307	Mitchell	-100.7622	32.3436	231DCKM	21	362	118	200	-	1,480	172	103	-	0.830	2,370	7.3
2942501	Mitchell	-100.8189	32.3111	231DCKM	21	119	32	178	4.0	443	315	64	-	-	1,053	8.2
2942601	Mitchell	-100.7750	32.3042	231DCKM	16	171	64	39	-	406	326	61	-	-	918	7.9
2942603	Mitchell	-100.7581	32.3278	231DCKM	20	89	27	33	-	90	253	56	-	-	463	7.5
2942802	Mitchell	-100.8014	32.2878	231DCKM	24	135	45	79	-	116	239	220	-	0.180	807	7.5
2942902	Mitchell	-100.7681	32.2508	231DCKM	21	113	46	50	-	188	377	65	-	0.420	670	7.7
2942907	Mitchell	-100.7781	32.2914	231DCKM	18	78	31	50	3.3	172	251	33	0.180	0.225	512	7.3
2943102	Mitchell	-100.7158	32.3675	231DCKM	35	85	29	32	-	108	248	63	-	0.350	475	7.5
2943103	Mitchell	-100.7250	32.3356	231DCKM	17	84	31	33	-	81	288	61	-	0.090	451	7.6
2943110	Mitchell	-100.7247	32.3364	231DCKM	15	126	47	69	-	166	288	169	-	0.350	749	7.4
2943119	Mitchell	-100.7239	32.3642	231DCKM	22	33	9	163	3.0	110	292	25	-	-	596	8.5
2943123	Mitchell	-100.7211	32.3444	231DCKM	37	155	38	30	-	300	236	50	-	0.380	727	8.2
2943209	Mitchell	-100.6789	32.3417	231DCKM	17	161	50	83	-	288	278	163	-	0.150	940	8.0
2943402	Mitchell	-100.7450	32.3181	231DCKM	19	73	33	29	-	102	239	56	-	0.180	432	7.8
2943404	Mitchell	-100.7300	32.3069	231DCKM	16	86	32	25	-	90	303	39	-	0.200	438	7.9
2943501	Mitchell	-100.6953	32.3267	231DCKM	35	87	19	22	-	67	221	63	-	0.280	406	7.4
2943502	Mitchell	-100.6803	32.2994	231DCKM	18	87	25	31	-	83	304	45	-	0.310	442	8.2
2943510	Mitchell	-100.6947	32.3147	231DCKM	40	63	43	36	-	97	218	82	-	0.340	495	8.0
2943522	Mitchell	-100.6922	32.3000	231DCKM	20	142	59	55	4.0	177	275	209	0.700	0.201	884	7.1
2943701	Mitchell	-100.7133	32.2853	231DCKM	18	29	32	26	-	85	301	32	-	0.300	371	7.5
2943804	Mitchell	-100.6681	32.2686	231DCKM	12	49	52	29	-	48	376	30	-	-	405	8.3
2943806	Mitchell	-100.6750	32.2539	231DCKM	11	110	80	62	7.5	264	386	133	-	0.340	860	6.7
2949201	Mitchell	-100.9503	32.2344	231DCKM	14	111	61	397	-	440	282	447	-	-	1,691	7.6
2949301	Mitchell	-100.8900	32.2467	231DCKM	15	209	47	137	8.9	681	387	37	0.100	0.226	1,327	6.8
2951106	Mitchell	-100.7311	32.2464	231DCKM	22	120	36	54	4.0	144	299	112	-	-	641	7.7
2863603	Sterling	-101.1300	32.0542	231DCKM	32	173	27	274	-	277	370	343	-	-	1,351	7.5
2864403	Sterling	-101.0978	32.0636	231DCKM	16	86	4	15	-	11	270	15	0.101	-	287	7.5
2864403	Sterling	-101.0978	32.0636	231DCKM	16	82	5	16	-	11	270	16	0.101	0.097	248	7.5
2864501	Sterling	-101.0806	32.0469	231DCKM	18	28	11	1	1.5	6	257	8	-	0.150	284	7.2
2864503	Sterling	-101.0647	32.0419	231DCKM	15	65	4	19	1.5	10	226	12	0.110	0.056	249	7.1

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2864503	Sterling	-101.0647	32.0419	231DCKM	15	65	4	19	1.5	10	226	12	0.080	0.093	246	7.2
2864901	Sterling	-101.0211	32.0331	231DCKM	14	54	13	28	0.2	22	223	30	-	-	280	7.7
4309806	Sterling	-100.9550	31.7697	231DCKM	16	69	28	31	-	33	321	42	-	-	379	7.7
4310703	Sterling	-100.8594	31.7878	231DCKM	21	73	39	27	-	24	392	27	-	-	413	7.7
4310712	Sterling	-100.8597	31.7864	231DCKM	25	71	36	24	1.6	22	391	23	0.150	0.097	407	7.0
4408604	Sterling	-101.0319	31.9342	231DCKM	18	56	19	6	1.0	12	254	7	-	0.150	254	7.5
2855101*	Howard	-101.2444	32.2397	231DCKM	58	1,500	340	1,600	31.0	740	-	5,600	23.000	0.970	9,930	7.6
2840612	Mitchell	-101.0144	32.4183	231DCKM	-	258	213	327	-	1,590	277	238	1.280	-	2,834	7.15
2925715	Mitchell	-100.9700	32.5033	231DCKM	-	117	26	155	-	155	247	250	1.190	-	895	7.22
2927704	Mitchell	-100.7294	32.5069	231DCKM	-	102	48	148	-	193	266	231	1.250	-	982	7.32
2933807	Mitchell	-100.9197	32.3781	231DCKM	-	197	56	129	-	515	300	134	0.680	-	1,275	7.12
2934435	Mitchell	-100.8464	32.4239	231DCKM	-	59	38	79	-	166	320	29	0.170	-	554	7.36
2941705	Mitchell	-100.9861	32.2586	231DCKM	12	331	234	563	10.7	1,776	342	500	2.380	-	3,639	7.21
2917903	Nolan	-100.8925	32.6458	231DCKM	18	25	11	118	1.9	75	323	27	0.145	0.342	438	7.8
2935301	Nolan	-100.6503	32.4653	231DCKM	26	86	37	54	5.7	150	314	50	-	0.210	566	7.0
2935313	Nolan	-100.6381	32.4733	231DCKM	16	92	46	63	-	217	321	51	-	0.400	645	7.9
2935319	Nolan	-100.6397	32.4672	231DCKM	35	78	30	53	5.0	160	260	42	-	-	534	8.0
2935322	Nolan	-100.6381	32.4650	231DCKM	23	224	81	98	4.6	283	292	351	1.340	0.520	1,279	7.8
2935601	Nolan	-100.6397	32.4203	231DCKM	14	87	22	37	-	74	251	77	-	0.360	436	7.6
2935603	Nolan	-100.6394	32.4519	231DCKM	17	81	37	32	-	102	331	29	-	0.470	463	7.6
2935905	Nolan	-100.6383	32.4142	231DCKM	13	68	21	28	2.0	44	276	34	-	0.820	349	7.7
2935907	Nolan	-100.6661	32.4044	231DCKM	13	65	22	26	-	36	260	40	-	0.380	331	7.9
2936107	Nolan	-100.5878	32.4906	231DCKM	16	53	34	63	9.0	84	351	32	-	-	467	8.3
2936109	Nolan	-100.5883	32.4900	231DCKM	23	102	42	85	13.6	111	386	119	0.44	0.680	702	7.3
2936110	Nolan	-100.6175	32.4739	231DCKM	18	109	56	76	9.2	340	331	52	0.240	0.352	829	7.2
2936208	Nolan	-100.5453	32.4764	231DCKM	-	209	112	74	12.0	319	204	416	1.700	-	1,347	6.7
2936401	Nolan	-100.6233	32.4200	231DCKM	14	80	25	23	-	75	288	31	-	0.270	392	8.2
2936403	Nolan	-100.6225	32.4206	231DCKM	-	82	27	26	4.2	85	295	29	0.360	-	404	6.9
2936414	Nolan	-100.6128	32.4225	231DCKM	15	81	24	29	-	59	248	54	-	0.320	400	7.7
2936416	Nolan	-100.5994	32.4419	231DCKM	14	51	33	25	-	109	185	39	-	0.370	364	7.9
2936421	Nolan	-100.6192	32.4200	231DCKM	17	67	22	19	2.3	39	281	26	0.145	0.131	335	7.2
2936501	Nolan	-100.5467	32.4447	231DCKM	21	128	35	51	11.0	188	273	110	0.220	0.550	717	7.2

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2936502	Nolan	-100.5467	32.4450	231DCKM	21	129	34	47	11.0	176	272	100	-	-	685	7.3
2936503	Nolan	-100.5464	32.4450	231DCKM	24	93	39	24	-	144	232	71	-	-	516	-
2936504	Nolan	-100.5450	32.4439	231DCKM	21	138	39	55	13.0	136	283	155	0.250	0.570	770	7.1
2936505	Nolan	-100.5439	32.4378	231DCKM	-	132	32	40	-	106	265	134	-	-	631	7.4
2936529	Nolan	-100.5458	32.4431	231DCKM	22	144	35	45	8.6	147	249	146	0.610	0.255	720	7.1
2936601	Nolan	-100.5389	32.4389	231DCKM	21	94	27	31	6.0	74	257	75	-	0.340	476	7.1
2936602	Nolan	-100.5317	32.4461	231DCKM	-	117	31	54	7.0	158	279	98	-	-	635	7.4
2936604	Nolan	-100.5172	32.4336	231DCKM	29	67	22	25	-	46	237	51	-	-	362	8.0
2936610	Nolan	-100.5164	32.4303	231DCKM	30	75	24	24	3.7	44	226	78	0.160	0.270	401	7.4
2936614	Nolan	-100.5386	32.4386	231DCKM	21	88	21	17	4.9	55	243	60	-	-	394	7.4
2936615	Nolan	-100.5386	32.4386	231DCKM	19	92	22	11	5.3	55	256	50	-	-	391	7.6
2936702	Nolan	-100.6050	32.3847	231DCKM	12	68	21	24	-	32	268	36	-	0.290	327	7.9
2936811	Nolan	-100.5806	32.4114	231DCKM	22	68	20	14	-	39	261	24	-	0.280	316	7.3
2936814	Nolan	-100.5467	32.3872	231DCKM	42	310	53	250	7.1	494	239	479	1.100	0.720	1,951	7.3
2936820	Nolan	-100.5689	32.3911	231DCKM	15	60	14	28	-	36	204	43	-	0.300	299	7.6
2936825	Nolan	-100.5553	32.4089	231DCKM	-	76	17	16	4.0	34	261	36	0.240	-	324	7.1
2936905	Nolan	-100.5186	32.3864	231DCKM	16	115	14	33	-	61	279	88	-	-	476	7.9
2936926	Nolan	-100.5214	32.3872	231DCKM	16	160	26	40	3.7	109	226	221	0.860	0.106	729	7.1
2943313	Nolan	-100.6589	32.3661	231DCKM	20	139	34	131	2.3	298	314	134	1.140	0.361	991	7.1
2943602	Nolan	-100.6342	32.2944	231DCKM	19	296	59	401	-	540	278	660	-	0.690	2,285	7.7
2943606	Nolan	-100.6331	32.2953	231DCKM	20	253	45	263	7.5	432	272	399	1.080	0.633	1,729	7.6
2943902	Nolan	-100.6311	32.2575	231DCKM	15	131	59	101	-	309	380	97	-	0.480	902	7.7
2944102	Nolan	-100.6086	32.3667	231DCKM	15	61	30	27	2.5	36	297	36	-	0.080	354	7.4
2944104	Nolan	-100.5978	32.3503	231DCKM	18	94	15	40	-	57	265	64	-	0.200	434	8.0
2944116	Nolan	-100.6183	32.3344	231DCKM	15	98	16	37	-	62	272	73	-	0.260	439	7.8
2944125	Nolan	-100.6208	32.3339	231DCKM	14	71	14	23	2.0	62	203	39	-	-	335	7.9
2944308	Nolan	-100.5294	32.3617	231DCKM	12	43	7	15	-	15	149	16	-	0.230	185	7.7
2944309	Nolan	-100.5114	32.3450	231DCKM	15	81	2	14	1.0	15	243	17	-	-	273	8.2
2944417	Nolan	-100.6117	32.3300	231DCKM	13	76	10	14	2.0	20	272	17	-	-	290	8.3
2944418	Nolan	-100.6092	32.3164	231DCKM	13	77	18	19	2.2	36	288	28	0.144	0.092	336	7.2
2944501	Nolan	-100.5825	32.3175	231DCKM	8	143	16	72	-	132	288	142	-	-	654	7.1
2944704	Nolan	-100.5989	32.2514	231DCKM	16	99	2	19	1.0	37	259	28	-	-	350	8.0

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2944705	Nolan	-100.6053	32.2683	231DCKM	13	73	19	28	-	50	288	23	-	-	349	8.2
2944901	Nolan	-100.5275	32.2550	231DCKM	11	73	19	18	-	46	245	31	-	0.420	319	7.6
2945101	Nolan	-100.4975	32.3456	231DCKM	14	90	6	15	1.0	23	283	19	-	-	312	7.9
2959304	Nolan	-100.6428	32.0883	231DCKM	14	80	45	31	-	97	357	42	-	-	485	8.1
2808501	Scurry	-101.0625	32.9194	231DCKM	10	5	2	536	1.4	466	577	136	0.400	1.773	1,470	8.8
2808801	Scurry	-101.0775	32.8814	231DCKM	10	3	2	582	-	338	702	240	-	-	1,525	8.1
2808901	Scurry	-101.0039	32.8972	231DCKM	9	3	1	328	-	182	465	72	-	-	854	8.8
2815301	Scurry	-101.1558	32.8464	231DCKM	40	125	55	51	-	178	283	92	-	-	812	7.5
2815501	Scurry	-101.1672	32.8178	231DCKM	46	46	12	92	4.6	28	294	47	0.250	0.245	433	7.3
2815602	Scurry	-101.1611	32.8325	231DCKM	47	46	18	46	-	13	311	11	-	-	337	8.1
2815603	Scurry	-101.1594	32.8311	231DCKM	51	49	23	53	4.0	14	273	57	0.190	0.168	396	6.8
2815604	Scurry	-101.1606	32.8328	231DCKM	47	47	20	36	3.5	13	201	20	0.090	0.099	293	7.4
2816301	Scurry	-101.0092	32.8692	231DCKM	10	1	1	240	-	94	427	44	-	-	615	8.7
2824201	Scurry	-101.0792	32.7444	231DCKM	29	58	10	28	-	12	249	25	-	-	286	8.0
2824301	Scurry	-101.0189	32.7097	231DCKM	11	35	18	1,650	-	494	358	2,080	-	0.970	4,465	7.5
2824303	Scurry	-101.0064	32.7239	231DCKM	23	77	29	165	-	110	294	210	-	-	762	8.2
2824304	Scurry	-101.0228	32.7481	231DCKM	15	5	1	260	-	784	-	109	-	-	1,177	3.7
2824502	Scurry	-101.0689	32.7006	231DCKM	10	6	4	598	-	273	535	441	-	-	1,600	8.3
2824701	Scurry	-101.1225	32.6319	231DCKM	35	121	41	470	-	374	368	560	-	-	1,789	7.0
2824702	Scurry	-101.1164	32.6494	231DCKM	10	18	7	1,590	-	750	592	1,600	-	-	4,271	7.6
2824704*	Scurry	-101.1181	32.6492	231DCKM	8	26	12	1,200	4.5	400	-	1,400	2.300	1.700	3,260	8.2
2824901	Scurry	-101.0253	32.6381	231DCKM	13	33	16	1,300	4.6	331	460	1,590	-	1.200	3,514	8.1
2824902	Scurry	-101.0183	32.6431	231DCKM	11	5	3	205	1.2	66	426	37	-	0.480	539	8.2
2824903	Scurry	-101.0197	32.6444	231DCKM	11	3	3	238	1.1	78	433	57	-	0.670	615	8.5
2832201	Scurry	-101.0547	32.6094	231DCKM	18	63	15	85	1.0	124	273	26	-	-	498	7.5
2832202	Scurry	-101.0539	32.6092	231DCKM	23	62	9	96	1.0	44	320	31	-	-	472	7.4
2832204	Scurry	-101.0600	32.6114	231DCKM	36	106	14	21	1.0	48	238	17	-	-	473	7.2
2832208*	Scurry	-101.0697	32.5925	231DCKM	18	680	420	210	7.0	2,600	-	570	3.800	0.230	4,810	6.8
2832301	Scurry	-101.0303	32.6100	231DCKM	22	220	106	176	4.0	960	331	78	-	-	1,729	7.2
2832302	Scurry	-101.0311	32.6114	231DCKM	24	184	106	160	7.0	853	322	70	-	0.490	1,562	7.1
2832304	Scurry	-101.0019	32.5939	231DCKM	24	302	147	178	5.8	1,000	271	364	2.080	0.040	2,159	7.0
2832601	Scurry	-101.0239	32.5786	231DCKM	21	355	224	290	-	1,570	397	330	-	-	2,998	6.9

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2832603*	Scurry	-101.0192	32.5464	231DCKM	22	350	110	530	5.2	2,000	-	91	0.600	0.210	3,310	7.1
2832807	Scurry	-101.0669	32.5319	231DCKM	45	104	31	229	-	284	324	188	-	-	1,110	7.0
2901501	Scurry	-100.9197	32.9239	231DCKM	3	22	18	69	14.0	33	310	19	-	-	330	7.8
2901601	Scurry	-100.8981	32.9389	231DCKM	25	89	36	30	3.5	125	308	38	0.250	0.091	497	6.8
2909201	Scurry	-100.9208	32.8558	231DCKM	12	10	5	149	-	44	318	40	-	-	416	8.0
2909302	Scurry	-100.8986	32.8583	231DCKM	16	44	24	129	2.9	139	423	25	0.090	0.378	591	7.3
2909402	Scurry	-100.9811	32.8275	231DCKM	15	14	4	166	2.0	73	400	13	-	-	485	8.3
2909403	Scurry	-100.9608	32.7928	231DCKM	24	106	33	79	-	14	315	212	-	-	624	7.8
2909601	Scurry	-100.8767	32.8142	231DCKM	26	62	19	40	-	47	282	24	-	-	359	7.3
2909701	Scurry	-100.9622	32.7822	231DCKM	25	54	14	32	-	12	284	8	-	-	288	7.2
2909702	Scurry	-100.9597	32.7556	231DCKM	27	44	16	55	-	25	306	14	-	-	333	7.7
2909704	Scurry	-100.9933	32.7550	231DCKM	33	59	19	48	-	38	259	55	-	-	383	8.0
2909801	Scurry	-100.9267	32.7511	231DCKM	20	127	34	108	-	48	243	310	-	-	771	7.0
2909803	Scurry	-100.9475	32.7894	231DCKM	21	56	19	72	-	22	315	64	-	-	410	7.6
2909805	Scurry	-100.9225	32.7722	231DCKM	34	68	18	14	-	11	309	9	-	-	313	7.7
2909808	Scurry	-100.9189	32.7717	231DCKM	34	70	17	18	3.0	13	309	16	-	-	328	7.6
2909813	Scurry	-100.9189	32.7508	231DCKM	-	70	30	200	-	201	178	253	-	-	844	7.5
2909905	Scurry	-100.9142	32.7508	231DCKM	30	44	16	33	3.0	18	243	18	-	-	286	8.1
2909910	Scurry	-100.9008	32.7511	231DCKM	38	156	50	60	5.2	176	222	228	1.250	0.234	877	6.6
2910501	Scurry	-100.7950	32.8111	231DCKM	12	15	5	174	-	84	344	38	-	-	505	8.5
2910602	Scurry	-100.7783	32.7939	231DCKM	12	6	2	145	1.4	59	312	18	0.078	0.536	404	8.3
2910902	Scurry	-100.7858	32.7900	231DCKM	23	99	33	162	4.5	291	276	144	-	0.390	939	7.0
2911701	Scurry	-100.7178	32.7842	231DCKM	17	92	64	103	6.0	352	279	91	-	-	877	8.1
2917105	Scurry	-100.9806	32.7397	231DCKM	43	295	69	124	8.7	265	187	492	1.890	0.353	1,461	6.8
2917106	Scurry	-100.9886	32.7125	231DCKM	31	43	20	63	3.7	33	283	43	0.216	0.235	378	7.3
2917107	Scurry	-100.9747	32.7272	231DCKM	8	57	21	133	9.2	151	205	180	0.090	0.244	664	7.8
2917201	Scurry	-100.9219	32.7458	231DCKM	31	490	104	494	-	0	194	1,810	-	-	3,038	6.4
2917202	Scurry	-100.9219	32.7456	231DCKM	33	60	19	14	-	10	252	22	-	-	290	7.0
2917205	Scurry	-100.9531	32.7261	231DCKM	39	178	71	129	9.0	108	244	462	-	0.390	1,176	7.1
2917206	Scurry	-100.9181	32.7467	231DCKM	27	48	14	50	3.0	22	287	20	-	-	330	8.2
2917211	Scurry	-100.9189	32.7156	231DCKM	-	187	10	88	-	64	268	271	-	-	777	7.4
2917213	Scurry	-100.9181	32.7475	231DCKM	-	99	33	44	-	25	331	123	-	-	494	7.5

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2917214	Scurry	-100.9181	32.7411	231DCKM	-	96	32	76	-	52	353	119	-	-	557	7.4
2917215	Scurry	-100.9275	32.7189	231DCKM	28	273	81	280	9.9	180	257	860	-	-	1,863	7.0
2917217	Scurry	-100.9172	32.7133	231DCKM	24	66	24	94	3.6	88	312	73	0.415	0.312	543	7.3
2917302	Scurry	-100.9147	32.7447	231DCKM	23	57	19	67	-	43	305	53	-	-	415	7.7
2917308	Scurry	-100.9136	32.7172	231DCKM	-	114	13	53	-	66	334	67	-	-	512	7.3
2917309	Scurry	-100.8950	32.7175	231DCKM	-	156	57	54	-	143	227	255	-	-	809	7.4
2917310	Scurry	-100.9011	32.7172	231DCKM	-	120	42	68	-	116	315	144	-	-	668	7.2
2917311	Scurry	-100.9072	32.7097	231DCKM	-	42	18	60	-	26	311	14	-	-	318	7.5
2917313	Scurry	-100.9111	32.7283	231DCKM	-	109	24	43	-	66	295	81	-	-	500	7.5
2917401	Scurry	-100.9983	32.6683	231DCKM	12	2	1	337	-	108	414	203	-	-	868	8.0
2917402	Scurry	-100.9997	32.6911	231DCKM	18	15	6	135	2.0	43	338	24	-	-	410	8.2
2917403	Scurry	-100.9992	32.6681	231DCKM	20	3	1	527	-	135	388	460	-	-	1,365	8.6
2917404	Scurry	-100.9978	32.6786	231DCKM	-	447	133	798	8.0	116	183	2,229	-	-	3,883	7.8
2917505*	Scurry	-100.9556	32.7072	231DCKM	22	220	140	680	10.0	1,100	-	910	0.740	2.200	3,220	7.6
2917701	Scurry	-100.9936	32.6500	231DCKM	13	27	21	258	-	271	400	71	-	-	861	7.8
2917703	Scurry	-100.9989	32.6564	231DCKM	14	3	1	328	-	100	371	184	-	-	846	0.0
2917704	Scurry	-100.9742	32.6417	231DCKM	23	54	18	54	3.3	50	319	24	-	0.300	386	7.5
2917706	Scurry	-100.9714	32.6425	231DCKM	28	236	53	208	4.7	291	399	330	1.26	1.007	1,407	6.8
2917802	Scurry	-100.9214	32.6264	231DCKM	12	12	5	277	-	192	443	59	-	-	778	8.3
2917903	Scurry	-100.8867	32.6458	231DCKM	16	24	10	122	2.0	86	328	28	0.090	0.323	452	7.8
2918104	Scurry	-100.8461	32.7097	231DCKM	41	106	43	40	5.0	85	250	150	-	-	640	8.2
2918204	Scurry	-100.8236	32.7178	231DCKM	35	98	23	25	6.7	24	232	134	0.090	0.130	482	7.3
2918401	Scurry	-100.8456	32.6858	231DCKM	33	143	50	118	5.2	223	278	251	1.200	0.372	1,018	6.7
2918402	Scurry	-100.8689	32.6939	231DCKM	31	200	50	154	7.0	219	273	413	-	-	1,241	8.0
2918403	Scurry	-100.8689	32.7039	231DCKM	35	115	47	53	6.0	71	292	203	-	-	694	7.6
2918508	Scurry	-100.8225	32.7072	231DCKM	27	54	18	39	4.0	31	284	26	-	-	342	8.2
2918701	Scurry	-100.8353	32.6386	231DCKM	20	90	24	30	2.8	44	268	48	0.330	0.114	407	7.0
2918802	Scurry	-100.7936	32.6619	231DCKM	23	36	14	63	3.6	25	287	16	-	0.340	324	7.7
2918902	Scurry	-100.7625	32.6358	231DCKM	19	79	22	75	4.3	176	250	57	0.230	0.199	564	7.3
2918908	Scurry	-100.7606	32.6344	231DCKM	21	67	23	74	4.1	176	272	34	0.090	0.220	547	7.3
2918910	Scurry	-100.7622	32.6367	231DCKM	20	81	24	74	4.4	193	267	51	0.090	0.198	588	7.3
2919203	Scurry	-100.6911	32.7297	231DCKM	24	69	12	52	-	37	233	20	-	-	422	7.7

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2919204	Scurry	-100.6908	32.7303	231DCKM	26	81	15	45	2.1	42	290	20	0.510	0.110	445	7.0
2919205	Scurry	-100.6931	32.7289	231DCKM	30	82	18	57	2.7	49	288	39	0.090	0.136	475	7.3
2919801	Scurry	-100.7003	32.6656	231DCKM	39	87	16	47	7.0	51	282	64	0.480	0.186	460	6.9
2925104	Scurry	-100.9889	32.5906	231DCKM	17	263	192	510	-	1,240	312	600	-	-	3,197	7.4
2925105	Scurry	-100.9894	32.5908	231DCKM	23	71	27	61	1.0	132	300	27	-	-	490	7.5
2925106	Scurry	-100.9906	32.5900	231DCKM	17	93	67	286	4.0	110	284	550	-	-	1,268	7.5
2925107	Scurry	-100.9903	32.5914	231DCKM	1	228	193	760	-	192	7	1,990	-	-	3,370	6.5
2925108	Scurry	-100.9950	32.5914	231DCKM	18	80	31	278	1.0	414	364	146	-	-	1,148	7.6
2925109	Scurry	-100.9925	32.5933	231DCKM	21	67	25	69	1.0	132	279	34	-	-	493	7.6
2925110	Scurry	-100.9886	32.5958	231DCKM	20	223	114	123	3.0	650	297	271	-	-	1,556	7.3
2925404	Scurry	-100.9725	32.5556	231DCKM	-	400	150	5,550	-	1,500	391	8,400	-	-	16,192	7.0
2925405	Scurry	-100.9761	32.5586	231DCKM	19	266	100	240	9.0	1,043	350	158	-	0.720	2,007	7.0
2925501	Scurry	-100.9292	32.5711	231DCKM	21	84	19	220	-	267	285	146	-	-	985	8.1
2925707*	Scurry	-100.9642	32.5292	231DCKM	21	580	160	520	7.9	350	-	2,000	13.000	0.240	3,780	7.1
2925711	Scurry	-100.9803	32.5328	231DCKM	9	224	71	3,752	11.0	778	250	5,838	-	-	10,806	8.3
2925713	Scurry	-100.9803	32.5403	231DCKM	12	416	112	4,007	11.0	1,116	265	6,240	-	-	12,047	8.1
2925803	Scurry	-100.9333	32.5375	231DCKM	20	200	84	142	6.0	734	332	109	-	0.750	1,458	8.1
2926401*	Scurry	-100.8747	32.5633	231DCKM	20	330	110	360	4.0	1,300	-	350	3.100	0.410	2,610	7.3
2926502	Scurry	-100.8006	32.5711	231DCKM	16	224	50	216	-	329	368	368	-	-	1,471	8.2
2926601	Scurry	-100.7639	32.5808	231DCKM	18	39	10	74	-	43	250	40	-	-	349	7.9
2927702	Scurry	-100.7336	32.5317	231DCKM	36	87	39	277	-	403	329	202	-	-	1,220	8.4
2958903	Coke	-100.7533	32.0183	300PLZC	-	9,640	1,970	51,300	-	1,000	200	99,000	-	-	163,008	6.2
2959724	Coke	-100.7461	32.0181	300PLZC	-	2,480	1,080	30,400	-	3,420	573	51,600	-	-	89,261	7.9
2959726	Coke	-100.7336	32.0339	300PLZC	-	3,000	1,230	31,900	-	3,550	458	55,500	-	-	95,405	7.7
2963702	Coke	-100.2461	32.0058	300PLZC	-	3,290	1,220	34,100	-	2,040	525	60,100	-	-	101,008	6.8
2950603*	Mitchell	-100.7672	32.2019	310PRMN	18	580	250	260	6.4	1,700	-	980	2.300	0.550	3,900	7.4
2951701*	Mitchell	-100.7183	32.1411	310PRMN	4	310	83	1,500	10.0	4,200	-	340	0.600	8.100	6,480	7.3
2958611	Coke	-100.7856	32.0719	312OCHO	42	810	150	580	6.0	1,800	-	1,600	2.800	0.450	5,040	8.1
2958901	Coke	-100.7678	32.0228	312OCHO	21	625	100	92	5.3	1,780	218	105	-	-	2,839	7.3
2959511	Coke	-100.6858	32.0489	312OCHO	26	688	85	226	3.2	102	314	1,560	-	-	2,849	6.8
2959601	Coke	-100.6308	32.0808	312OCHO	24	214	92	42	2.8	660	272	57	-	-	1,226	7.4
4318204	Coke	-100.8058	31.7217	312OCHO	-	83	32	23	-	23	400	22	-	-	389	7.7

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
2959505*	Coke	-100.6719	32.0711	313ARTS	4	120	88	470	20.0	590	-	800	8.000	0.340	2,180	7.8
2959802	Coke	-100.6800	32.0383	313ARTS	26	87	17	33	-	59	237	63	-	-	417	7.0
2959804	Coke	-100.6719	32.0056	313ARTS	19	455	106	559	4.1	1,250	188	980	-	-	3,468	7.5
2959904	Coke	-100.6267	32.0083	313ARTS	21	545	161	147	3.5	1,980	188	102	-	-	3,055	7.6
2960405	Coke	-100.6033	32.0536	313ARTS	23	592	107	62	4.0	1,888	112	53	-	-	2,785	7.7
2960502	Coke	-100.5556	32.0803	313ARTS	27	492	107	137	3.6	1,630	164	84	-	-	2,564	7.4
2960803*	Coke	-100.5494	32.0139	313ARTS	20	540	110	69	3.5	1,500	-	130	0.900	0.210	2,460	7.4
2960804	Coke	-100.5433	32.0083	313ARTS	24	74	20	30	2.1	74	238	41	-	-	387	8.0
2960901	Coke	-100.5186	32.0089	313ARTS	26	475	223	321	3.7	1,980	260	370	-	-	3,606	7.4
2960903	Coke	-100.5231	32.0261	313ARTS	21	610	63	37	2.5	1,610	204	35	-	-	2,479	7.6
2960907	Coke	-100.5019	32.0164	313ARTS	24	462	141	124	3.0	1,320	274	270	-	-	2,501	7.3
2961401	Coke	-100.4989	32.0694	313ARTS	13	66	30	10	2.0	44	304	12	-	-	329	7.7
2962802	Coke	-100.2967	32.0217	313ARTS	10	93	107	31	-	317	406	68	-	-	826	8.1
2963401	Coke	-100.2447	32.0664	313ARTS	9	61	36	73	7.3	130	356	26	-	-	518	7.6
4303503	Coke	-100.6994	31.9356	313ARTS	29	67	41	37	-	50	369	51	-	-	461	8.0
4303601	Coke	-100.6264	31.9178	313ARTS	15	695	207	410	4.5	2,000	200	900	-	-	4,355	7.6
4303904*	Coke	-100.6500	31.9042	313ARTS	18	620	180	210	3.6	2,000	-	290	1.400	0.500	3,470	7.2
4304101	Coke	-100.5889	31.9908	313ARTS	20	550	136	162	4.4	1,840	162	163	-	-	2,963	7.2
4304201	Coke	-100.5603	31.9808	313ARTS	18	310	82	67	4.8	976	173	75	-	-	1,619	7.3
4304301	Coke	-100.5300	31.9631	313ARTS	28	110	48	55	2.4	214	352	57	-	-	692	7.6
4304302	Coke	-100.5172	31.9794	313ARTS	16	308	84	80	4.0	1,045	157	71	-	-	1,686	7.9
4304601	Coke	-100.5342	31.9253	313ARTS	23	480	29	33	2.3	1,150	186	38	-	-	1,853	7.1
4304702	Coke	-100.6117	31.8861	313ARTS	27	120	32	76	2.8	222	252	108	-	-	715	7.3
4304704	Coke	-100.5983	31.9033	313ARTS	24	235	75	346	4.7	864	214	422	-	-	2,087	7.1
4304705	Coke	-100.5933	31.8964	313ARTS	14	360	158	517	-	1,378	150	812	-	-	3,313	7.6
4304803	Coke	-100.5694	31.8853	313ARTS	16	625	191	461	6.3	1,960	176	840	-	-	4,211	7.6
4305302*	Coke	-100.3794	31.9731	313ARTS	13	210	190	300	17.0	1,400	-	290	1.700	0.960	2,520	8.2
4305402	Coke	-100.4997	31.9344	313ARTS	23	565	161	194	4.7	1,750	222	332	-	-	3,155	7.2
4312101	Coke	-100.6161	31.8350	313ARTS	30	280	100	113	3.2	692	346	253	-	-	1,645	7.3
4312204	Coke	-100.5686	31.8675	313ARTS	29	358	170	143	4.7	1,210	194	358	-	-	2,374	7.1
4312206	Coke	-100.5678	31.8669	313ARTS	28	87	41	87	2.0	157	366	88	-	-	671	7.9
4312302	Coke	-100.5300	31.8392	313ARTS	5	565	194	870	24.0	2,450	24	1,100	-	-	5,224	6.6

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4319401	Coke	-100.7197	31.6961	313ARTS	19	69	45	30	2.0	40	365	55	-	-	451	8.4
4201601	Runnels	-99.8967	31.9339	318ARRY	23	202	64	188	-	160	277	474	-	-	1,357	8.0
4201602	Runnels	-99.8861	31.9558	318ARRY	22	114	73	84	-	99	357	213	-	-	861	8.1
4201606	Runnels	-99.8789	31.9383	318ARRY	21	184	104	81	-	530	365	136	-	-	1,242	8.1
4201903	Runnels	-99.9003	31.8931	318ARRY	18	101	207	411	-	319	520	810	-	-	2,194	8.2
4202104	Runnels	-99.8347	31.9639	318ARRY	15	122	109	182	-	243	351	351	-	-	1,355	8.1
4202105	Runnels	-99.8586	31.9617	318ARRY	25	113	76	150	-	288	333	132	-	-	1,128	7.9
4202201	Runnels	-99.7956	31.9853	318ARRY	11	293	293	622	-	246	271	1,932	-	-	3,531	7.7
4202202	Runnels	-99.8036	31.9656	318ARRY	12	216	77	130	-	423	240	332	-	-	1,330	8.0
4202401	Runnels	-99.8531	31.9278	318ARRY	23	114	56	76	-	100	329	156	-	-	788	8.0
4202402	Runnels	-99.8681	31.9242	318ARRY	22	172	73	167	-	232	303	349	-	-	1,294	8.0
4202901	Runnels	-99.7886	31.9061	318ARRY	17	119	35	199	-	180	312	211	-	-	1,076	7.9
4209202	Runnels	-99.9333	31.8542	318ARRY	20	112	173	123	-	407	265	352	-	-	1,446	7.7
4209303	Runnels	-99.9153	31.8536	318ARRY	20	69	88	182	-	197	375	192	-	-	1,105	8.2
4217407	Runnels	-99.9719	31.7064	318ARRY	39	110	50	211	-	216	467	198	-	-	1,105	8.0
4217408	Runnels	-99.9978	31.6794	318ARRY	23	233	109	350	-	351	249	710	-	-	2,115	7.8
4217713	Runnels	-99.9961	31.6281	318ARRY	24	354	93	304	-	920	196	344	-	-	2,474	7.8
4217716	Runnels	-99.9953	31.6411	318ARRY	20	215	125	291	-	312	267	640	-	-	2,005	8.1
4225108	Runnels	-99.9969	31.5917	318ARRY	24	251	98	386	-	314	259	800	-	-	2,182	7.5
4316902	Runnels	-100.0047	31.7681	318ARRY	21	139	68	239	-	203	259	350	-	-	1,401	7.8
4324301	Runnels	-100.0083	31.7092	318ARRY	22	168	73	230	-	289	304	416	-	-	1,492	8.1
4324302	Runnels	-100.0400	31.7339	318ARRY	18	492	221	149	-	1,480	279	266	-	-	3,105	7.7
4324303	Runnels	-100.0314	31.7092	318ARRY	18	620	118	235	-	1,380	285	590	-	-	3,127	7.5
4324504	Runnels	-100.0522	31.6719	318ARRY	17	183	154	176	-	260	282	550	-	-	1,690	7.8
4324602	Runnels	-100.0383	31.6911	318ARRY	18	1,010	322	1,020	-	1,390	304	3,100	-	-	7,020	7.4
4324803	Runnels	-100.0436	31.6533	318ARRY	18	530	220	286	-	1,670	273	520	-	-	3,460	7.8
4324804	Runnels	-100.0425	31.6597	318ARRY	19	433	188	258	-	1,190	279	481	-	-	3,002	7.6
4324805	Runnels	-100.0739	31.6314	318ARRY	14	570	182	213	-	1,370	272	510	-	-	3,284	7.4
4324806	Runnels	-100.0431	31.6492	318ARRY	18	590	156	348	-	550	338	680	-	-	3,812	7.4
4324807	Runnels	-100.0597	31.6419	318ARRY	19	275	149	375	-	452	232	800	-	-	2,565	7.5
4324808	Runnels	-100.0825	31.6275	318ARRY	17	245	73	389	-	520	220	560	-	-	2,195	7.8
4324903	Runnels	-100.0058	31.6372	318ARRY	21	232	134	273	-	358	237	700	-	-	2,045	8.0

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4324904	Runnels	-100.0075	31.6372	318ARRY	22	168	90	97	-	252	365	225	-	-	1,189	7.7
4324905	Runnels	-100.0225	31.6397	318ARRY	16	443	127	211	-	880	226	520	-	-	2,569	7.8
4324906	Runnels	-100.0308	31.6444	318ARRY	23	165	45	262	-	259	282	278	-	-	1,463	7.6
4324907	Runnels	-100.0269	31.6536	318ARRY	21	336	178	223	-	326	227	880	-	-	2,376	7.5
4324908	Runnels	-100.0261	31.6661	318ARRY	21	181	114	161	-	150	268	520	-	-	1,489	7.6
4331303	Runnels	-100.1539	31.6019	318ARRY	21	73	37	86	-	78	244	129	-	-	609	8.2
4331304	Runnels	-100.1547	31.6031	318ARRY	21	60	33	89	-	72	254	106	-	-	562	8.1
4331305	Runnels	-100.1481	31.6069	318ARRY	28	156	72	139	-	139	288	360	-	-	1,131	8.0
4331308	Runnels	-100.1436	31.6097	318ARRY	23	196	85	196	-	103	354	440	-	-	1,488	7.4
4331310	Runnels	-100.1600	31.5928	318ARRY	23	64	9	24	-	13	168	5	-	-	330	7.9
4331603	Runnels	-100.1381	31.5828	318ARRY	24	159	94	205	-	184	333	465	-	-	1,416	7.4
4331604	Runnels	-100.1439	31.5814	318ARRY	25	175	65	205	-	208	265	430	-	-	1,352	7.6
4332101	Runnels	-100.0922	31.5853	318ARRY	25	161	71	158	-	126	270	432	-	-	1,187	7.9
4332102	Runnels	-100.0881	31.6181	318ARRY	24	175	67	195	-	205	264	429	-	-	1,316	7.6
4332103	Runnels	-100.0939	31.6039	318ARRY	24	207	76	326	-	432	256	520	-	-	1,873	7.5
4332104	Runnels	-100.1011	31.5844	318ARRY	23	163	78	235	-	287	265	395	-	-	1,493	7.6
4332105	Runnels	-100.1083	31.6122	318ARRY	23	83	27	191	-	165	259	115	-	-	959	7.9
4332208	Runnels	-100.0592	31.6156	318ARRY	16	660	175	223	-	1,810	234	420	-	-	3,626	7.7
4332209	Runnels	-100.0569	31.5936	318ARRY	22	211	109	339	-	387	257	630	-	-	2,076	8.0
4332210	Runnels	-100.0558	31.5939	318ARRY	23	274	155	185	-	274	220	670	-	-	2,031	7.8
4332211	Runnels	-100.0633	31.5886	318ARRY	24	232	89	197	-	216	343	388	-	-	1,726	7.5
4332212	Runnels	-100.0639	31.5881	318ARRY	27	417	89	192	-	202	326	510	-	-	2,389	7.3
4332213	Runnels	-100.0472	31.6197	318ARRY	23	443	194	493	-	680	329	1,070	-	-	3,607	7.6
4332306	Runnels	-100.0264	31.6172	318ARRY	20	173	120	121	-	203	326	386	-	-	1,368	7.9
4332307	Runnels	-100.0153	31.6183	318ARRY	19	389	115	283	-	471	281	760	-	-	2,470	7.5
4332308	Runnels	-100.0206	31.5889	318ARRY	24	330	107	237	-	189	282	630	-	-	2,218	7.4
4332309	Runnels	-100.0406	31.6233	318ARRY	20	330	140	240	-	312	223	820	-	-	2,233	7.8
4332310	Runnels	-100.0378	31.5919	318ARRY	22	221	72	255	-	254	240	580	-	-	1,654	7.8
4332405	Runnels	-100.0939	31.5808	318ARRY	15	620	231	444	-	1,940	244	730	-	-	4,323	7.7
4332503	Runnels	-100.0814	31.5831	318ARRY	25	155	64	175	-	178	254	373	-	-	1,206	7.8
4201401	Runnels	-99.9639	31.9347	318BLGN	22	189	175	472	-	401	383	820	-	-	2,597	7.9
4308802	Runnels	-100.0428	31.8831	318BLGN	22	183	31	142	-	92	265	154	-	-	1,213	7.8

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4308901	Runnels	-100.0347	31.8831	318BLGN	20	140	25	153	-	162	232	173	-	-	1,030	8.0
4315902	Runnels	-100.1278	31.7850	318BLGN	0	115	46	155	-	125	207	116	-	-	1,093	8.4
4323703	Runnels	-100.2122	31.6267	318BLGN	21	98	55	100	-	70	337	137	-	-	818	8.0
4323801	Runnels	-100.1944	31.6361	318BLGN	16	121	86	150	-	113	316	405	-	-	1,068	7.6
4226502	Runnels	-99.8200	31.5828	318BLPL	44	159	27	413	-	397	339	436	-	-	1,795	7.5
4226503	Runnels	-99.8286	31.5828	318BLPL	26	288	15	165	-	71	179	463	-	-	1,442	7.4
2963901	Runnels	-100.1411	32.0344	318CHOZ	16	415	170	150	-	1,760	92	60	-	-	2,628	7.8
2963902	Runnels	-100.1578	32.0231	318CHOZ	22	101	24	50	-	59	293	83	-	-	525	7.9
2964404	Runnels	-100.1117	32.0481	318CHOZ	-	216	30	118	-	71	178	350	-	-	1,106	8.4
2964501	Runnels	-100.0478	32.0506	318CHOZ	20	198	116	208	-	127	293	600	-	-	1,644	7.8
2964601	Runnels	-100.0222	32.0561	318CHOZ	26	178	60	165	-	168	282	327	-	-	1,279	7.6
2964602	Runnels	-100.0153	32.0661	318CHOZ	17	393	105	140	-	123	287	730	-	-	2,039	7.4
2964603	Runnels	-100.0136	32.0661	318CHOZ	19	209	78	155	-	172	270	429	-	-	1,405	7.7
2964604	Runnels	-100.0219	32.0569	318CHOZ	26	183	67	177	-	172	265	387	-	-	1,335	7.6
2964605	Runnels	-100.0386	32.0528	318CHOZ	21	360	64	214	-	241	245	700	-	-	1,941	7.7
2964704	Runnels	-100.0853	32.0236	318CHOZ	22	119	35	121	-	106	261	207	-	-	858	7.9
2964802	Runnels	-100.0806	32.0403	318CHOZ	25	111	33	145	-	99	222	248	-	-	890	7.8
2964901	Runnels	-100.0222	32.0086	318CHOZ	28	246	53	184	-	155	256	413	-	-	1,525	7.7
2964902	Runnels	-100.0397	32.0417	318CHOZ	25	249	86	186	-	146	238	590	-	-	1,609	7.8
3057402	Runnels	-99.9714	32.0497	318CHOZ	25	173	48	227	-	131	244	285	-	-	1,507	7.7
3057403	Runnels	-99.9711	32.0439	318CHOZ	26	144	28	100	-	75	246	107	-	-	906	7.7
3057703	Runnels	-99.9731	32.0178	318CHOZ	24	264	134	294	-	233	216	770	-	-	2,247	7.6
3057704	Runnels	-99.9711	32.0250	318CHOZ	26	151	32	148	-	102	267	141	-	-	1,097	7.8
3057705	Runnels	-99.9867	32.0275	318CHOZ	28	167	26	190	-	211	287	226	-	-	1,232	7.6
3057706	Runnels	-99.9631	32.0175	318CHOZ	13	156	69	190	-	200	390	408	-	-	1,241	7.9
3057707	Runnels	-99.9650	32.0150	318CHOZ	16	229	159	286	-	266	530	780	-	-	1,999	7.8
3057708	Runnels	-99.9881	32.0261	318CHOZ	20	122	19	187	-	155	289	157	-	-	1,000	7.8
4308103	Runnels	-100.1211	31.9783	318CHOZ	22	226	60	97	-	52	289	296	-	-	1,279	7.5
4308104	Runnels	-100.1139	31.9936	318CHOZ	24	154	73	109	-	102	310	209	-	-	1,148	7.5
4308404	Runnels	-100.0917	31.9247	318CHOZ	23	234	64	115	-	116	438	207	-	-	1,358	7.6
4308501	Runnels	-100.0692	31.9442	318CHOZ	21	117	25	127	-	91	260	147	-	-	844	7.7
4308502	Runnels	-100.0711	31.9578	318CHOZ	25	222	42	269	-	45	356	600	-	-	1,533	7.6

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4308601	Runnels	-100.0017	31.9417	318CHOZ	29	307	71	289	-	231	226	790	-	-	1,979	7.6
4315302	Runnels	-100.1300	31.8706	318CHOZ	27	193	45	202	-	156	296	387	-	-	1,341	7.3
4315303	Runnels	-100.1256	31.8694	318CHOZ	25	179	49	224	-	151	483	337	-	-	1,313	7.7
4315402	Runnels	-100.2111	31.8197	318CHOZ	21	142	66	301	-	245	331	255	-	-	1,697	7.8
4316101	Runnels	-100.0919	31.8492	318CHOZ	0	154	26	247	-	174	323	233	-	-	1,280	7.4
4316102	Runnels	-100.1161	31.8489	318CHOZ	20	106	45	119	-	129	244	232	-	-	822	8.0
4316103	Runnels	-100.1247	31.8700	318CHOZ	20	143	35	129	-	145	265	237	-	-	930	7.5
4316104	Runnels	-100.1228	31.8706	318CHOZ	25	179	43	174	-	151	251	329	-	-	1,215	7.7
4316105	Runnels	-100.1250	31.8714	318CHOZ	0	130	41	164	-	150	312	234	-	-	976	8.4
4306802*	Coke	-100.3294	31.8958	318CLFK	5	390	360	470	19.0	2,500	-	440	2.300	0.880	4,340	7.2
4306807	Coke	-100.2992	31.8819	318CLFK	24	151	137	174	9.7	418	476	278	-	-	1,560	7.3
4314201	Coke	-100.3050	31.8347	318CLFK	-	206	61	58	-	534	240	69	-	-	1,084	-
4314204	Coke	-100.2931	31.8739	318CLFK	-	406	95	75	-	1,240	224	62	-	-	1,992	-
4314601	Coke	-100.2769	31.8097	318CLFK	17	608	93	96	6.5	1,670	220	141	-	0.940	2,740	7.2
4314602	Coke	-100.2781	31.8075	318CLFK	19	602	85	98	6.0	1,687	222	118	-	-	2,725	7.7
4314801	Coke	-100.3317	31.7814	318CLFK	10	117	89	96	13.0	417	443	62	-	-	1,023	7.6
4314901	Coke	-100.2761	31.7681	318CLFK	-	600	88	124	-	1,690	224	130	-	-	2,743	6.8
4322201	Coke	-100.2942	31.7269	318CLFK	-	368	125	128	-	1,120	256	240	-	-	2,106	7.5
4322301	Coke	-100.2878	31.7283	318CLFK	19	312	77	93	-	837	286	148	-	-	1,648	7.7
4322601	Coke	-100.2786	31.7033	318CLFK	16	310	79	100	7.2	1,100	183	61	-	-	1,764	7.4
2964401	Runnels	-100.1078	32.0431	318CLFK	25	165	58	125	-	122	301	282	-	-	1,123	7.6
2964701	Runnels	-100.1147	32.0089	318CLFK	25	109	29	129	-	81	368	113	-	-	825	8.4
3057401	Runnels	-99.9881	32.0519	318CLFK	19	80	20	166	-	140	266	96	-	-	819	8.0
3057702	Runnels	-99.9783	32.0122	318CLFK	31	133	39	184	-	164	272	231	-	-	1,133	7.8
4201105	Runnels	-99.9969	31.9897	318CLFK	15	53	9	9	-	6	205	11	-	-	204	7.6
4201107	Runnels	-99.9861	31.9919	318CLFK	19	211	93	189	-	118	326	590	-	-	1,469	7.4
4201901	Runnels	-99.9081	31.8978	318CLFK	24	158	73	206	-	172	293	415	-	-	1,330	7.5
4201902	Runnels	-99.9078	31.8983	318CLFK	26	152	63	196	-	180	298	379	-	-	1,278	8.1
4202701*	Runnels	-99.8586	31.8986	318CLFK	19	180	190	560	0.7	580	-	1,100	4.900	0.800	2,830	7.8
4209401	Runnels	-99.9878	31.8144	318CLFK	13	565	149	198	-	1,600	289	396	-	-	3,099	7.4
4209501*	Runnels	-99.9517	31.8081	318CLFK	17	450	340	450	1.9	1,100	-	1,400	5.600	0.630	4,000	7.1
4217401	Runnels	-99.9972	31.6819	318CLFK	20	180	62	173	-	274	268	296	-	-	1,305	7.9

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4217402	Runnels	-99.9750	31.6867	318CLFK	18	580	258	338	9.0	1,700	338	770	-	-	3,862	7.1
4217404	Runnels	-99.9672	31.6672	318CLFK	25	234	140	316	2.0	307	267	760	-	-	2,190	7.3
4217405	Runnels	-99.9964	31.6794	318CLFK	21	190	86	299	-	358	272	549	-	-	1,803	8.0
4217501	Runnels	-99.9569	31.6783	318CLFK	20	268	135	355	-	328	323	790	-	-	2,408	7.4
4217502	Runnels	-99.9569	31.6761	318CLFK	25	274	138	465	-	443	267	840	-	-	2,739	7.3
4217701	Runnels	-99.9797	31.6622	318CLFK	28	432	198	474	-	499	261	1,270	-	-	3,520	7.7
4217704	Runnels	-99.9722	31.6525	318CLFK	16	365	260	600	5.0	1,290	403	1,080	-	-	3,818	7.3
4217706	Runnels	-99.9769	31.6394	318CLFK	21	202	126	315	2.0	314	257	620	-	-	2,054	7.4
4217707	Runnels	-99.9836	31.6350	318CLFK	19	650	309	970	-	1,060	287	2,070	-	-	6,031	7.7
4217709	Runnels	-99.9767	31.6283	318CLFK	17	270	244	462	5.0	740	338	950	-	-	3,213	7.2
4217710	Runnels	-99.9800	31.6308	318CLFK	19	505	319	762	-	1,355	315	1,473	-	-	5,168	7.5
4217801	Runnels	-99.9486	31.6544	318CLFK	29	269	30	317	-	367	244	484	-	-	1,837	7.5
4217802	Runnels	-99.9583	31.6544	318CLFK	26	172	42	148	2.0	150	285	175	-	-	1,236	7.4
4217803	Runnels	-99.9389	31.6317	318CLFK	29	81	42	84	-	66	357	75	-	-	666	7.7
4225101	Runnels	-99.9853	31.6061	318CLFK	23	194	39	225	-	231	266	304	-	-	1,473	7.4
4225103	Runnels	-99.9850	31.6064	318CLFK	22	434	85	461	-	442	267	744	-	-	3,235	7.8
4225104	Runnels	-99.9953	31.6006	318CLFK	32	670	118	386	-	341	220	920	-	-	4,007	7.4
4225105	Runnels	-99.9942	31.5903	318CLFK	25	500	162	486	-	373	227	1,270	-	-	3,707	7.4
4225401	Runnels	-99.9900	31.5803	318CLFK	34	700	107	640	5.0	640	226	1,430	-	-	4,529	7.1
4308102	Runnels	-100.0867	31.9806	318CLFK	21	121	60	121	-	163	228	286	-	-	921	8.1
4308401	Runnels	-100.1003	31.9197	318CLFK	34	126	67	220	-	234	376	288	-	-	1,265	7.7
4308402	Runnels	-100.0994	31.9197	318CLFK	34	147	66	221	-	250	340	344	-	-	1,332	7.9
4315201	Runnels	-100.1983	31.8617	318CLFK	16	385	74	84	-	1,280	116	31	-	-	1,932	7.9
4315601	Runnels	-100.1364	31.8208	318CLFK	25	93	19	96	-	85	305	58	-	-	642	7.4
4315604*	Runnels	-100.1256	31.8208	318CLFK	27	131	33	157	-	126	217	153	-	-	1,051	8.1
4315605	Runnels	-100.1258	31.8136	318CLFK	14	472	81	570	-	2,121	217	285	-	-	3,651	7.8
4323501	Runnels	-100.2006	31.7086	318CLFK	19	158	70	140	-	236	237	381	-	-	1,159	8.1
4323601	Runnels	-100.1533	31.6839	318CLFK	17	268	213	338	-	1,203	306	452	-	-	2,837	8.0
4323602	Runnels	-100.1633	31.6836	318CLFK	20	172	173	335	-	563	259	598	-	-	2,321	8.1
4323701	Runnels	-100.2253	31.6394	318CLFK	22	130	65	76	2.6	93	305	260	-	-	799	7.0
4323901	Runnels	-100.1500	31.6411	318CLFK	20	117	49	112	4.0	112	248	243	-	-	871	7.5
4324802	Runnels	-100.0458	31.6506	318CLFK	21	870	300	680	4.8	1,200	-	2,200	7.900	1.100	5,430	6.8

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4331201	Runnels	-100.1836	31.5967	318CLFK	0	184	64	141	-	349	354	231	-	-	1,176	7.2
4331204	Runnels	-100.1936	31.5906	318CLFK	7	198	101	265	-	680	51	440	-	-	1,827	7.8
4331211	Runnels	-100.1878	31.5989	318CLFK	0	139	60	98	-	63	458	269	-	-	884	7.7
4331301	Runnels	-100.1586	31.5933	318CLFK	12	300	93	272	-	920	283	351	-	-	2,148	7.9
4332201	Runnels	-100.0658	31.6158	318CLFK	19	216	118	328	-	472	276	497	-	-	2,147	7.6
4332202	Runnels	-100.0569	31.6194	318CLFK	24	740	308	348	-	1,030	339	990	-	-	4,870	7.3
4332203	Runnels	-100.0533	31.6181	318CLFK	19	441	192	164	4.0	1,530	271	288	-	-	2,826	7.1
4332204	Runnels	-100.0531	31.6172	318CLFK	17	570	200	191	5.0	1,880	235	347	-	-	3,346	7.6
4332205	Runnels	-100.0536	31.6147	318CLFK	19	331	181	136	4.0	870	248	476	-	-	2,253	7.3
4332206	Runnels	-100.0542	31.6142	318CLFK	19	437	183	167	5.0	1,240	239	420	-	-	2,690	7.3
4332207	Runnels	-100.0531	31.6181	318CLFK	16	612	188	197	-	1,680	234	491	-	-	3,434	7.4
4332304	Runnels	-100.0225	31.6019	318CLFK	27	261	80	234	-	404	257	520	-	-	1,784	7.8
4209602	Runnels	-99.9136	31.8292	318LDRS	35	450	199	410	-	222	284	1,450	-	-	3,254	7.6
4209603	Runnels	-99.9039	31.8047	318LDRS	10	126	30	66	-	196	251	113	-	-	665	7.8
4209604	Runnels	-99.9156	31.8242	318LDRS	20	386	263	207	-	1,080	540	447	-	-	2,984	7.7
4210102	Runnels	-99.8414	31.8736	318LDRS	22	129	95	140	-	205	390	319	-	-	1,130	8.1
4217202	Runnels	-99.9558	31.7228	318LDRS	34	89	42	113	-	139	423	87	-	-	747	7.9
4217205	Runnels	-99.9528	31.7208	318LDRS	24	234	148	317	-	680	439	439	-	-	2,259	7.7
4217601	Runnels	-99.9081	31.6725	318LDRS	31	230	28	289	-	370	304	422	-	-	1,638	8.0
4217711	Runnels	-99.9658	31.6603	318LDRS	16	252	134	348	-	458	234	690	-	-	2,299	7.5
4217712	Runnels	-99.9658	31.6594	318LDRS	19	193	159	399	-	331	287	750	-	-	2,374	7.4
4217714	Runnels	-99.9864	31.6264	318LDRS	22	236	67	193	-	249	210	410	-	-	1,618	7.8
4217804	Runnels	-99.9536	31.6564	318LDRS	27	188	83	291	-	286	298	486	-	-	1,751	7.9
4217805	Runnels	-99.9467	31.6306	318LDRS	18	174	36	284	-	279	298	298	-	-	1,528	7.9
4217806	Runnels	-99.9497	31.6283	318LDRS	20	187	30	202	-	184	287	202	-	-	1,325	7.8
4217807	Runnels	-99.9481	31.6297	318LDRS	20	176	29	162	-	139	232	115	-	-	1,277	7.9
4217808	Runnels	-99.9425	31.6314	318LDRS	21	182	89	198	-	101	368	335	-	-	1,564	7.6
4217902	Runnels	-99.9133	31.6344	318LDRS	17	211	18	129	-	113	201	163	-	-	1,170	7.6
4225107	Runnels	-99.9669	31.5933	318LDRS	22	266	111	302	-	245	338	620	-	-	2,138	7.5
4225109	Runnels	-99.9603	31.6103	318LDRS	27	165	80	413	-	416	389	510	-	-	2,004	7.8
4225110	Runnels	-99.9622	31.6100	318LDRS	24	190	48	250	-	241	253	379	-	-	1,500	7.7
4225202	Runnels	-99.9250	31.6225	318LDRS	24	336	27	265	-	237	250	610	-	-	1,935	7.3

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4225403	Runnels	-99.9692	31.5792	318LDRS	19	210	91	270	-	256	282	458	-	-	1,864	7.7
4332311	Runnels	-100.0017	31.6161	318LDRS	29	476	81	357	-	330	229	740	-	-	2,948	7.8
4332601	Runnels	-100.0042	31.5792	318LDRS	26	333	86	297	-	253	174	840	-	-	2,172	7.6
4332602	Runnels	-100.0022	31.5792	318LDRS	29	276	87	328	-	493	337	481	-	-	2,205	7.5
2963903	Runnels	-100.1364	32.0017	318MRKL	21	244	91	235	-	170	284	580	-	-	1,780	7.5
2964402	Runnels	-100.1067	32.0428	318MRKL	18	72	34	63	-	43	285	110	-	-	509	8.0
2964403	Runnels	-100.1086	32.0469	318MRKL	20	174	59	105	-	84	229	315	-	-	1,079	7.8
2964405	Runnels	-100.1097	32.0442	318MRKL	25	116	40	100	-	70	279	187	-	-	806	7.9
2964406	Runnels	-100.1108	32.0458	318MRKL	22	119	51	94	-	65	251	198	-	-	873	7.8
2964702	Runnels	-100.1089	32.0411	318MRKL	29	261	82	143	-	184	232	341	-	-	1,685	7.8
2964703	Runnels	-100.1200	32.0083	318MRKL	24	128	28	107	-	60	275	213	-	-	780	7.5
4307302	Runnels	-100.1511	31.9867	318MRKL	22	210	69	239	-	172	254	550	-	-	1,552	7.6
2959725	Coke	-100.7408	32.0214	318PRVR	-	2,560	1,370	28,300	-	3,660	219	49,400	-	-	85,397	7.3
2962404	Coke	-100.3725	32.0497	318PRVR	9	52	21	459	-	943	206	48	-	-	1,634	7.6
2962502	Coke	-100.2975	32.0556	318PRVR	23	54	44	170	2.1	134	504	79	-	-	775	7.6
2962503	Coke	-100.2981	32.0567	318PRVR	27	92	49	112	4.0	215	398	71	-	-	783	8.0
2962505	Coke	-100.3069	32.0658	318PRVR	16	50	19	138	7.0	162	334	40	-	-	608	8.3
4304106	Coke	-100.5981	31.9783	318PRVR	8	2,460	1,140	26,000	441.0	3,940	338	45,200	-	2.800	79,356	6.3
4305502*	Coke	-100.4339	31.9411	318PRVR	12	16	52	2,200	41.0	4,100	-	440	1.500	5.800	7,130	7.9
4305901	Coke	-100.4114	31.9086	318PRVR	28	71	22	62	2.0	23	381	37	-	-	455	7.7
4306301*	Coke	-100.2756	31.9747	318PRVR	19	290	250	610	14.0	840	-	1,400	7.300	0.610	3,480	8.8
4306304	Coke	-100.2744	31.9925	318PRVR	17	101	120	63	6.0	339	342	186	-	0.150	1,000	8.3
4306602	Coke	-100.2686	31.9342	318PRVR	20	308	142	190	-	602	338	550	-	-	2,094	7.2
4306801	Coke	-100.3128	31.8939	318PRVR	-	148	105	145	-	649	336	107	-	-	1,337	-
4313304*	Coke	-100.4125	31.8653	318PRVR	5	640	330	580	24.0	2,900	-	740	3.800	1.100	5,270	8.3
4313601	Coke	-100.3914	31.7925	318PRVR	9	240	244	203	-	1,222	410	341	-	-	2,465	7.7
4313602	Coke	-100.3997	31.8094	318PRVR	9	156	73	1,310	-	820	465	1,690	-	-	4,289	7.9
4313603*	Coke	-100.3942	31.8233	318PRVR	8	110	100	980	24.0	570	-	1,400	3.100	1.400	3,340	8.2
4313705	Coke	-100.4647	31.7908	318PRVR	9	288	152	4,090	60.0	1,260	448	6,200	-	2.200	12,321	7.1
4313902	Coke	-100.3764	31.7644	318PRVR	7	185	212	114	16.0	872	500	215	-	-	1,868	7.2
4314207	Coke	-100.3008	31.8647	318PRVR	-	118	80	37	-	136	441	104	-	-	759	-
4314401	Coke	-100.3517	31.8067	318PRVR	-	188	126	282	27.0	1,010	356	215	-	-	2,024	7.2

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4321102	Coke	-100.4917	31.7431	318PRVR	-	535	96	331	14.0	1,870	254	230	-	-	3,202	7.5
4321601	Coke	-100.3886	31.7028	318PRVR	8	90	52	74	8.5	147	372	108	-	-	671	7.6
4324501*	Runnels	-100.0503	31.6836	318SDPP	18	260	200	400	3.8	1,000	-	640	1.900	0.630	2,700	7.2
4201202	Runnels	-99.9208	31.9647	318VALE	24	157	50	192	-	183	288	327	-	-	1,215	7.8
4201302	Runnels	-99.9000	31.9631	318VALE	21	178	37	94	-	89	238	293	-	-	959	7.6
4201502	Runnels	-99.9239	31.9197	318VALE	24	211	146	232	-	285	390	590	-	-	1,904	7.9
4201504	Runnels	-99.9400	31.9172	318VALE	23	214	128	242	-	197	273	700	-	-	1,849	7.7
4201603	Runnels	-99.9139	31.9419	318VALE	24	202	45	141	-	103	237	420	-	-	1,162	7.5
4201604	Runnels	-99.9131	31.9414	318VALE	23	145	35	107	-	82	232	306	-	-	845	7.7
4201605	Runnels	-99.9117	31.9303	318VALE	22	167	51	118	-	117	272	314	-	-	1,033	8.0
4201803	Runnels	-99.9425	31.9139	318VALE	22	161	98	265	-	213	304	530	-	-	1,619	8.1
4201804	Runnels	-99.9314	31.9042	318VALE	20	320	159	520	-	256	299	1,370	-	-	2,925	7.9
4201805	Runnels	-99.9314	31.9086	318VALE	7	610	483	500	-	286	173	2,960	-	-	4,954	4.6
4316201	Runnels	-100.0511	31.8350	318VALE	25	131	80	158	-	141	322	352	-	-	1,155	7.7
4316202	Runnels	-100.0594	31.8569	318VALE	23	86	24	211	-	220	306	126	-	-	981	8.0
4316203	Runnels	-100.0439	31.8519	318VALE	16	113	55	164	-	180	299	185	-	-	1,071	8.0
4316302	Runnels	-100.0253	31.8492	318VALE	21	208	62	245	-	199	221	560	-	-	1,575	7.6
4316501	Runnels	-100.0497	31.8194	318VALE	30	107	59	182	-	168	351	248	-	-	1,089	7.9
4316502	Runnels	-100.0472	31.7972	318VALE	30	94	35	142	-	79	244	143	-	-	865	8.1
4316602	Runnels	-100.0386	31.8078	318VALE	34	252	97	246	-	268	251	610	-	-	1,862	7.6
4316603	Runnels	-100.0392	31.8025	318VALE	24	128	101	192	-	145	311	396	-	-	1,352	8.2
4316802	Runnels	-100.0539	31.7847	318VALE	24	109	48	255	-	221	298	196	-	-	1,337	7.9
4316803	Runnels	-100.0442	31.7889	318VALE	35	127	52	118	-	91	255	141	-	-	1,044	8.0
4324401	Runnels	-100.0928	31.6989	318VALE	35	142	57	286	-	241	279	279	-	-	1,558	7.6
4324402	Runnels	-100.0936	31.6981	318VALE	36	197	65	343	-	299	277	333	-	-	1,984	7.6
4324502	Runnels	-100.0803	31.6981	318VALE	33	131	38	163	-	147	217	177	-	-	1,109	7.7
4324503	Runnels	-100.0786	31.7064	318VALE	28	173	67	254	-	248	172	405	-	-	1,588	7.6
4331208	Runnels	-100.1772	31.6128	318VALE	20	211	103	213	-	980	266	120	-	-	1,782	8.0
4331209	Runnels	-100.1967	31.6097	318VALE	21	133	68	202	-	111	311	355	-	-	1,226	7.7
4331210	Runnels	-100.2042	31.6011	318VALE	27	118	57	118	-	83	334	217	-	-	906	7.9
4331302	Runnels	-100.1578	31.6119	318VALE	23	131	72	164	-	145	250	387	-	-	1,136	8.0
4331306	Runnels	-100.1594	31.6231	318VALE	16	182	118	245	-	239	243	690	-	-	1,613	8.0

Designation	Co.	LongDD	LatDD	Aquifer (TWDB)	Si (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
4331307	Runnels	-100.1433	31.6061	318VALE	27	126	48	132	-	91	312	221	-	-	989	7.5
4331309	Runnels	-100.1436	31.6086	318VALE	27	179	64	131	-	60	312	356	-	-	1,151	7.6
4331311	Runnels	-100.1586	31.6153	318VALE	22	193	111	189	-	159	298	580	-	-	1,512	7.9
4217901	Runnels	-99.8981	31.6556	318WCHT	22	265	33	230	-	210	296	443	-	-	1,591	7.4
4217903	Runnels	-99.9014	31.6494	318WCHT	18	226	41	179	-	198	288	343	-	-	1,368	7.3
4217904	Runnels	-99.9089	31.6522	318WCHT	24	280	36	345	-	328	267	590	-	-	2,035	7.4
4225201	Runnels	-99.9203	31.5914	318WCHT	19	690	27	129	-	1,340	294	279	-	-	2,659	7.6
4225203	Runnels	-99.9272	31.5850	318WCHT	20	207	24	138	-	131	232	265	-	-	1,139	7.5
4225204	Runnels	-99.9186	31.5850	318WCHT	21	177	20	87	-	86	226	189	-	-	881	7.5

Appendix 3.3. Brine Hydrochemical Database

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
Mansfield+	OLDHAM	-102.3800	35.4400	salt-dissolution zone	1,530	430	24,000	49.0	5,900	39	35,100	7.800	-	67,086	7.5
Mansfield b+	OLDHAM	-102.4000	35.4100	salt-dissolution zone	1,460	388	23,850	32.0	5,610	41	36,120	6.200	-	67,530	7.2
Sawyer+	DONLEY	-100.8300	35.0900	salt-dissolution zone	1,940	500	35,000	46.0	5,100	66	53,100	22.000	-	95,812	6.6
Sawyer b+	DONLEY	-100.8700	35.0800	salt-dissolution zone	1,860	480	33,000	30.0	4,725	73	54,700	21.400	-	94,917	6.3
Harman+	SWISHER	-101.7500	34.6600	salt-dissolution zone	1,466	3,923	108,700	1,218	5760	-	166,800	52	-	287,948	6.3
SW10+	SWISHER	-101.7500	34.6600	salt-dissolution zone	1,731	4,040	110,700	1,293	201	-	205,700	58	-	293,954	-
Wendkirk	COKE	-100.3008	31.8417	STRAWN	8,790	1,630	39,200	244.1	356	121	80,680	412	7.45	131,800	6.7
42000023	COKE	-100.6800	32.0100	-	2,154	491	20,814	-	1,854	545	35,665	-	-	61,523	6.8
42000236	COKE	-100.6700	32.0400	-	12,898	1,823	52,233	-	408	15	108,403	-	-	176,261	5.2
42000239	COKE	-100.6700	32.0500	-	187	112	845	-	1,374	271	763	-	-	3,574	8.3
42000249	COKE	-100.6800	32.0700	-	7,759	1,047	49,301	-	865	129	92,078	-	-	151,179	5.8
42001295	COKE	-100.6900	32.0400	-	7,062	1,527	43,239	-	895	215	82,828	-	-	135,767	6.9
42001351	COKE	-100.7200	32.0100	-	1,510	487	13,339	-	2,774	245	28,592	-	-	40,843	6.3
42001352	COKE	-100.7200	32.0100	-	2,424	738	20,077	-	3,852	341	34,373	-	-	61,805	6.8
42002849	COKE	-100.6800	32.0300	-	10,961	2,242	49,322	-	282	154	101,686	-	-	164,648	5.9
42003042	COKE	-100.6900	31.9300	-	4,939	1,150	29,622	-	2,902	39	55,599	-	-	91,349	6.2
42003050	COKE	-100.6800	31.9000	-	2,457	1,093	29,502	-	3,699	12	50,289	-	-	87,051	5.8
42005096	COKE	-100.7000	32.0300	-	7,428	1,303	46,098	-	1,001	233	87,171	-	-	143,235	6.9
42018258	COKE	-100.7700	32.0000	-	2,427	1,178	20,372	-	3,723	244	36,251	-	-	64,196	6.7
42018265	COKE	-100.7700	32.0000	-	1,901	543	13,981	-	3,844	109	23,614	-	-	43,992	7.6
42254256	COKE	-100.7700	32.0000	-	4,084	972	19,849	-	317	298	40,325	-	-	65,936	6.4
42254258	COKE	-100.7700	32.0000	-	8,835	1,471	38,459	-	467	53	78,880	-	-	128,169	5.7
42254261	COKE	-100.7700	32.0000	-	4,603	821	28,002	-	398	146	53,777	-	-	88,051	6.5
42254262	COKE	-100.7700	32.0000	-	1,323	370	8,306	-	566	354	15,574	-	-	26,493	7.1
42254266	COKE	-100.7700	32.0000	-	5,322	724	32,438	-	585	195	61,428	-	-	101,184	7.3
42254267	COKE	-100.7700	32.0000	-	5,203	1,247	34,621	-	825	251	65,480	-	-	107,657	6.5
42254270	COKE	-100.7700	32.0000	-	5,636	1,298	38,296	-	860	181	72,048	-	-	118,319	6.6
42254272	COKE	-100.7700	32.0000	-	6,998	1,112	41,528	-	858	148	79,499	-	-	130,788	7.2
42254277	COKE	-100.7700	32.0000	-	3,492	642	22,657	-	560	201	42,696	-	-	70,516	7.6
42254278	COKE	-100.7700	32.0000	-	6,875	1,505	36,599	-	452	207	72,548	-	-	118,194	6.4
42254289	COKE	-100.7700	32.0000	-	5,300	1,247	35,267	-	682	208	66,770	-	-	109,476	6.6
42254293	COKE	-100.7700	32.0000	-	3,554	775	23,558	-	324	244	44,592	-	-	73,053	6.9
42254294	COKE	-100.7700	32.0000	-	5,140	1,181	34,450	-	0	-3	65,036	-	-	106,714	6.6
42254297	COKE	-100.7700	32.0000	-	3,665	741	25,066	-	704	276	46,551	-	-	77,004	6.6
42254304	COKE	-100.7700	32.0000	-	3,691	966	30,081	-	3,240	171	53,238	-	-	91,388	6.7
42254305	COKE	-100.6700	32.0100	-	1,257	277	10,425	-	300	271	18,704	-	-	31,247	6.5
42254311	COKE	-100.7700	32.0000	-	10,795	1,765	57,712	-	134	549	115,423	-	-	188,132	5.8
42254316	COKE	-100.7700	32.0000	-	4,139	940	28,658	-	645	259	53,707	-	-	88,349	7.2
42254317	COKE	-100.7700	32.0000	-	5,104	952	32,748	-	751	232	61,536	-	-	101,325	7.0
42254324	COKE	-100.6700	32.0100	-	1,215	299	10,319	-	318	276	18,493	-	-	30,921	7.4
42254325	COKE	-	-	-	5,304	994	30,741	-	871	149	59,027	-	-	97,191	6.5
42254326	COKE	-100.7700	32.0000	-	5,063	1,148	34,115	-	583	181	64,368	-	-	105,461	6.7
42254327	COKE	-100.7700	32.0000	-	6,114	1,301	39,136	-	782	193	74,152	-	-	121,678	6.7
42254328	COKE	-100.7700	32.0000	-	9,236	1,321	33,892	-	465	266	72,006	-	-	117,188	6.7
42254329	COKE	-100.7700	32.0000	-	5,908	1,147	39,392	-	802	227	73,806	-	-	121,283	6.6
42254330	COKE	-100.7700	32.0000	-	5,487	1,251	33,352	-	670	199	67,883	-	-	108,843	6.8
42254331	COKE	-100.7700	32.0000	-	5,513	1,038	34,898	-	802	251	68,938	-	-	111,442	6.5
42254332	COKE	-100.7700	32.0000	-	5,289	1,215	35,589	-	713	221	67,092	-	-	110,121	6.3
42254333	COKE	-100.7700	32.0000	-	5,290	1,075	35,485	-	649	212	66,669	-	-	109,381	6.6

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42254335	COKE	-100.7700	32.0000	-	6,596	2,507	51,262	-	761	138	104,682	-	-	165,946	6.0
42254336	COKE	-100.7700	32.0000	-	594	105	3,470	-	525	173	6,525	-	-	11,392	7.2
42254337	COKE	-	-	-	3,427	907	22,708	-	614	276	43,103	-	-	71,036	6.7
42254339	COKE	-100.7700	32.0000	-	5,276	1,303	35,104	-	576	106	66,762	-	-	109,141	6.0
42254340	COKE	-100.7700	32.0000	-	2,219	474	15,589	-	448	295	28,804	-	-	47,830	7.3
42254341	COKE	-100.7700	32.0000	-	3,767	773	23,887	-	657	207	45,249	-	-	74,541	5.9
42254342	COKE	-100.7700	32.0000	-	5,729	851	34,938	-	617	178	65,790	-	-	108,113	6.9
42254343	COKE	-100.7700	32.0000	-	2,500	1,030	25,300	-	3,580	64	43,800	-	-	76,276	6.0
42254344	COKE	-100.7700	32.0000	-	5,134	1,128	35,449	-	853	293	66,278	-	-	109,136	6.5
42254345	COKE	-100.7700	32.0000	-	2,805	549	18,596	-	625	276	34,595	-	-	57,447	6.2
42254346	COKE	-100.7700	32.0000	-	3,754	1,030	24,043	-	60	212	46,503	-	-	75,609	7.0
42254347	COKE	-100.7700	32.0000	-	5,398	1,099	36,527	-	479	254	68,637	-	-	112,395	6.7
42254348	COKE	-100.7700	32.0000	-	3,923	964	25,803	-	948	276	48,645	-	-	80,559	6.7
42254352	COKE	-100.7700	32.0000	-	7,459	486	49,696	-	959	198	90,356	-	-	149,154	6.0
42254355	COKE	-100.7700	32.0000	-	4,481	787	28,884	-	728	263	54,051	-	-	89,194	5.7
42254356	COKE	-100.7700	32.0000	-	8,473	1,734	39,149	-	460	117	80,152	-	-	130,126	6.3
42254359	COKE	-100.7700	32.0000	-	5,244	1,268	39,008	-	1,020	165	72,213	-	-	118,918	6.6
42254360	COKE	-100.7700	32.0000	-	11,095	2,199	55,983	-	508	66	111,966	-	-	181,870	5.4
42254361	COKE	-100.7700	32.0000	-	5,142	1,060	36,792	-	852	217	68,098	-	-	112,162	6.6
42254363	COKE	-100.7700	32.0000	-	3,497	744	23,529	-	757	327	43,907	-	-	72,761	7.2
42254364	COKE	-100.7700	32.0000	-	4,019	692	26,366	-	689	215	49,410	-	-	81,674	7.4
42254366	COKE	-100.7700	32.0000	-	3,532	876	24,498	-	683	240	48,575	-	-	78,404	6.7
42254367	COKE	-100.7700	32.0000	-	4,685	979	31,912	-	739	266	59,555	-	-	98,136	7.0
42254368	COKE	-100.7700	32.0000	-	3,215	658	21,638	-	583	249	40,598	-	-	67,164	7.6
42000006	COKE	-100.6500	32.0600	CADDO	7,392	1,276	45,923	-	1,067	140	86,767	-	-	142,565	6.7
42000018	COKE	-100.6900	32.0700	CADDO	7,140	1,171	43,404	-	1,068	237	82,071	-	-	135,091	6.7
42000024	COKE	-100.6800	32.0100	CADDO	7,459	1,407	47,215	-	991	227	89,264	-	-	146,563	6.7
42000025	COKE	-100.6800	32.0100	CADDO	7,530	1,508	46,396	-	983	188	88,449	-	-	145,054	6.9
42018261	COKE	-	-	CADDO	9,890	1,774	53,341	-	753	85	104,346	-	-	170,189	7.0
42255411	COKE	-100.7000	31.9700	CADDO	9,739	1,617	50,225	-	839	49	98,748	-	-	161,217	5.4
42002867	COKE	-100.6800	32.0100	CANYON	14,439	2,480	68,640	-	115	0	138,529	-	-	224,203	5.1
42002868	COKE	-100.6600	32.0100	CANYON	2,665	927	26,663	-	2,249	407	46,635	-	-	79,546	6.6
42019364	COKE	-	-	CANYON	11,266	2,496	37,614	-	24	30	85,172	-	-	136,603	6.6
42105425	COKE	-100.5900	31.9800	CANYON	12,769	3,017	-	-	-	192	120,910	-	-	195,987	6.2
42254306	COKE	-100.6700	32.0100	CANYON	3,161	607	24,680	-	249	183	45,159	-	-	74,045	6.5
42254307	COKE	-	-	CANYON	3,960	729	26,719	-	150	190	50,059	-	-	81,817	6.5
42255415	COKE	-100.5800	32.0100	CANYON	9,203	1,512	51,651	-	830	124	99,644	-	-	162,965	6.7
42018257	COKE	-	-	CANYON CISCO	2,102	522	7,544	-	3,827	112	13,993	-	-	28,100	7.8
42251294	COKE	-100.6900	32.0200	CANYON REEF	4,984	1,078	30,955	-	602	239	59,241	-	-	97,111	6.6
42251312	COKE	-100.6900	32.0200	CANYON REEF	832	247	5,931	-	262	256	11,050	-	-	18,579	7.4
42251313	COKE	-100.6900	32.0200	CANYON REEF	1,365	369	8,201	-	361	278	15,688	-	-	26,261	7.3
42251314	COKE	-100.6900	32.0200	CANYON REEF	3,744	931	25,737	-	762	256	48,310	-	-	79,741	6.5
42105426	COKE	-100.5900	31.9800	CANYON SAND, REEF	16,117	3,064	-	-	-	179	125,985	-	-	202,663	6.2
42007541	COKE	-100.7700	32.0000	CISCO	2,767	1,043	29,329	-	3,761	481	50,102	-	-	87,482	6.5
42007542	COKE	-100.7700	32.0000	CISCO	2,920	1,055	28,927	-	3,724	450	49,834	-	-	86,911	6.6
42007543	COKE	-100.7700	32.0000	CISCO	2,690	1,038	30,035	-	3,792	530	50,993	-	-	89,078	6.5
42000238	COKE	-100.6700	32.0500	CRINOIDAL	10,937	1,988	58,595	-	803	9	114,857	-	-	187,271	6.0
42001248	COKE	-100.6800	32.0500	CRINOIDAL	8,179	1,805	54,263	-	1,708	67	102,099	-	-	168,122	5.6
42000237	COKE	-100.6700	32.0600	ELLENBURGER	4,687	677	22,227	-	1,988	560	48,817	-	-	72,782	7.0
42105428	COKE	-100.4000	31.8100	ELLENBURGER	11,300	2,891	-	-	1,337	289	89,352	-	-	145,136	6.4

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42254299	COKE	-100.7700	32.0000	ELLENBURGER	1,831	1,936	17,175	-	2,092	703	33,725	-	-	57,619	6.3
42255421	COKE	-100.4900	32.0600	ELLENBURGER	1,938	479	22,201	-	2,176	662	37,085	-	-	64,542	6.8
42000037	COKE	-100.7000	32.0500	JAMESON REEF	7,182	1,446	44,825	-	987	195	85,222	-	-	139,857	6.5
42000049	COKE	-100.7000	32.0300	JAMESON REEF	7,370	1,342	44,419	-	986	208	84,618	-	-	138,943	6.5
42002528	COKE	-100.6700	32.0400	JAMESON REEF	7,577	2,046	39,300	-	1,273	170	78,933	-	-	129,299	-
42002619	COKE	-100.6900	32.0100	JAMESON REEF	5,329	1,220	28,998	-	1,350	262	56,548	-	-	93,707	7.2
42007513	COKE	-100.7700	32.0000	JAMESON REEF	1,080	267	16,345	-	4,799	113	24,251	-	-	46,887	8.7
42001349	COKE	-100.7200	32.0100	JAMESON STRAWN	5,591	879	30,919	-	7	21	60,112	-	-	97,530	6.2
42002798	COKE	-100.7100	32.0100	JAMESON STRAWN REEF	7,064	1,389	46,447	-	931	145	87,393	-	-	143,369	7.7
42254291	COKE	-100.7700	32.0000	LIME	6,075	1,524	42,137	-	835	195	79,374	-	-	130,140	6.3
42254349	COKE	-100.7700	32.0000	LIME	3,392	859	18,684	-	558	226	36,846	-	-	60,566	6.7
42251300	COKE	-100.7100	32.0000	LIME HILL	5,002	1,202	35,644	-	597	227	66,671	-	-	109,343	6.8
42002556	COKE	-100.6900	31.9200	MILLICAN REEF	22,468	1,758	37,724	-	419	169	102,638	-	-	165,175	6.2
42001328	COKE	-100.6900	32.0500	PENNSYLVANIAN	7,262	1,334	47,566	-	900	179	89,312	-	-	146,552	6.7
42002622	COKE	-100.4100	31.8400	PENNSYLVANIAN	12,748	1,621	44,795	-	19	91	96,284	-	-	155,557	6.5
42002817	COKE	-100.6000	32.0400	PENNSYLVANIAN	5,146	1,084	28,472	-	525	137	55,877	-	-	91,431	6.7
42002822	COKE	-100.5800	31.9900	PENNSYLVANIAN	11,447	1,473	40,240	-	20	43	86,555	-	-	139,778	5.8
42005111	COKE	-100.6900	32.0200	PENNSYLVANIAN	2,983	954	30,314	-	3,570	222	47,695	-	-	82,923	6.3
42007547	COKE	-	-	PENNSYLVANIAN	83	31	3,026	-	2,727	632	2,575	-	-	9,132	7.5
42007553	COKE	-	-	PENNSYLVANIAN	3,759	643	19,238	-	450	114	37,792	-	-	61,996	6.4
42251045	COKE	-100.6800	32.0400	PENNSYLVANIAN	7,881	1,393	35,306	-	321	146	72,124	-	-	117,179	6.2
42002821	COKE	-100.5800	31.9800	PENNSYLVANIAN REEF	16,976	3,190	42,582	-	682	311	104,310	-	-	168,051	6.1
42007548	COKE	-	-	PENNSYLVANIAN REEF	8,984	1,696	48,328	-	824	132	95,274	-	-	155,906	6.0
42007549	COKE	-	-	PENNSYLVANIAN REEF	6,963	1,298	39,927	-	1,180	227	77,986	-	-	128,080	6.0
42007552	COKE	-	-	PENNSYLVANIAN REEF	8,229	1,464	45,857	-	933	209	89,242	-	-	146,505	6.1
42007563	COKE	-100.5900	31.9700	PENNSYLVANIAN REEF	19,588	2,518	44,018	-	313	79	109,593	-	-	176,108	6.2
42254283	COKE	-	-	PENNSYLVANIAN REEF	8,637	1,622	47,844	-	847	167	93,665	-	-	153,451	6.2
42255417	COKE	-100.5800	32.0100	PENNSYLVANIAN SAND	12,310	1,813	46,066	-	14	113	98,020	-	-	158,338	6.4
42000242	COKE	-100.7200	31.9900	SAN ANGELO	2,185	791	19,497	-	3,304	211	33,674	-	-	59,662	6.7
42007474	COKE	-100.7700	32.0000	SAN ANGELO	2,640	1,272	27,926	-	3,773	292	49,044	-	-	85,565	6.6
42007475	COKE	-100.7700	32.0000	SAN ANGELO	2,601	1,215	26,184	-	3,865	227	46,029	-	-	80,668	6.7
42018242	COKE	-100.7700	32.0000	SAN ANGELO	2,735	1,191	33,194	-	3,915	274	56,464	-	-	97,773	7.2
42018243	COKE	-100.7700	32.0000	SAN ANGELO	2,686	1,283	31,249	-	3,953	260	53,626	-	-	93,056	6.6
42018245	COKE	-100.7700	32.0000	SAN ANGELO	2,765	1,350	35,204	-	3,953	267	60,060	-	-	103,599	7.3
42018246	COKE	-100.7700	32.0000	SAN ANGELO	2,837	1,232	31,431	-	3,992	243	54,007	-	-	93,743	6.4
42018247	COKE	-100.7700	32.0000	SAN ANGELO	2,736	1,186	31,189	-	3,864	273	53,400	-	-	92,649	7.1
42018248	COKE	-100.7700	32.0000	SAN ANGELO	2,734	1,395	24,352	-	3,789	167	43,579	-	-	76,018	6.9
42018255	COKE	-100.7700	32.0000	SAN ANGELO	2,636	1,293	23,139	-	3,712	139	41,305	-	-	72,227	7.1
42018256	COKE	-100.7700	32.0000	SAN ANGELO	2,635	1,455	25,591	-	3,813	195	45,453	-	-	79,142	6.9
42251308	COKE	-100.7000	32.0400	SNRF	4,765	984	32,052	-	849	283	59,830	-	-	98,764	6.7
42000003	COKE	-100.6700	32.0500	STRAWN	42,672	1,600	63,183	-	450	200	133,010	-	-	215,553	6.7
42000016	COKE	-100.6900	32.0500	STRAWN	7,224	1,451	45,363	-	948	156	86,193	-	-	141,333	6.1

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42000019	COKE	-100.6900	32.0600	STRAWN	7,716	1,459	49,315	-	971	33	93,238	-	-	152,731	7.9
42000020	COKE	-100.6900	32.0600	STRAWN	7,603	1,110	47,438	-	943	182	89,059	-	-	146,335	6.6
42000021	COKE	-100.6900	32.0600	STRAWN	7,433	1,451	47,255	-	199	117	89,524	-	-	146,693	6.9
42000022	COKE	-100.6900	32.0600	STRAWN	7,654	1,473	48,847	-	951	136	92,401	-	-	151,463	7.7
42000026	COKE	-100.6800	32.0100	STRAWN	13,707	2,106	53,061	-	83	65	112,139	-	-	181,161	6.5
42000027	COKE	-100.6800	32.0100	STRAWN	13,415	2,063	52,937	-	114	32	111,303	-	-	179,865	6.7
42000028	COKE	-100.7100	32.0300	STRAWN	7,245	1,285	45,149	-	1,045	368	85,221	-	-	140,311	6.7
42000031	COKE	-100.7000	32.0400	STRAWN	7,349	1,464	44,991	-	998	156	85,841	-	-	140,798	7.0
42000032	COKE	-100.7100	32.0300	STRAWN	6,738	1,093	43,043	-	311	356	79,591	-	-	131,242	6.9
42000034	COKE	-100.7100	32.0300	STRAWN	13,221	1,874	54,511	-	202	73	112,748	-	-	182,629	5.7
42000038	COKE	-100.7000	32.0500	STRAWN	7,453	1,337	47,830	-	1,021	158	90,017	-	-	147,816	6.3
42000039	COKE	-100.7000	32.0500	STRAWN	7,571	1,443	47,695	-	1,032	182	90,302	-	-	148,225	7.2
42000040	COKE	-100.7000	32.0500	STRAWN	7,384	1,390	47,156	-	986	162	89,032	-	-	146,109	7.7
42000041	COKE	-100.7000	32.0500	STRAWN	7,575	1,342	45,952	-	1,029	105	87,376	-	-	143,379	6.4
42000042	COKE	-100.7000	32.0500	STRAWN	7,141	1,367	45,720	-	993	-1	86,411	-	-	141,633	5.6
42000044	COKE	-100.7000	32.0500	STRAWN	7,721	1,269	47,686	-	135	166	85,370	-	-	139,902	8.9
42000045	COKE	-100.7000	32.0300	STRAWN	7,339	1,329	45,775	-	1,014	167	86,599	-	-	142,224	6.3
42000046	COKE	-100.7000	32.0300	STRAWN	6,514	1,386	40,694	-	1,667	160	77,012	-	-	127,432	6.3
42000047	COKE	-100.7000	32.0300	STRAWN	7,407	1,272	45,945	-	1,007	208	86,602	-	-	142,660	7.0
42000048	COKE	-100.7000	32.0300	STRAWN	7,487	1,425	47,277	-	1,017	195	89,461	-	-	146,862	7.2
42000050	COKE	-100.7000	32.0300	STRAWN	7,467	1,381	46,005	-	995	188	87,358	-	-	143,394	7.5
42000051	COKE	-100.7000	32.0300	STRAWN	7,518	1,364	45,724	-	1,117	280	86,818	-	-	142,822	7.2
42000052	COKE	-100.7000	32.0300	STRAWN	7,575	1,399	45,622	-	1,015	232	86,969	-	-	142,813	6.6
42000235	COKE	-100.6800	32.0600	STRAWN	12,761	1,988	52,039	-	667	55	108,095	-	-	175,604	5.7
42000243	COKE	-100.6400	32.0100	STRAWN	12,124	1,980	50,026	-	371	83	104,042	-	-	168,624	6.0
42000244	COKE	-100.6500	32.0200	STRAWN	10,244	1,222	38,805	-	1,015	24	80,765	-	-	132,075	5.0
42000247	COKE	-100.6800	31.8900	STRAWN	11,643	1,853	52,105	-	604	43	105,869	-	-	172,118	5.5
42000248	COKE	-100.7200	32.0000	STRAWN	13,509	1,862	58,247	-	1,084	59	118,305	-	-	193,066	5.6
42001158	COKE	-100.6900	32.0300	STRAWN	8,796	1,896	49,537	-	476	158	97,027	-	-	157,889	6.2
42001160	COKE	-100.6900	32.0300	STRAWN	10,014	1,840	50,687	-	430	25	100,931	-	-	163,927	5.1
42001161	COKE	-100.6900	32.0300	STRAWN	10,065	1,967	50,099	-	463	64	100,439	-	-	163,097	6.0
42001162	COKE	-100.6900	32.0300	STRAWN	9,891	1,748	50,179	-	450	0	99,660	-	-	161,928	5.5
42001163	COKE	-100.6900	32.0300	STRAWN	9,745	1,656	47,091	-	419	130	94,324	-	-	153,365	6.6
42001164	COKE	-100.6900	32.0300	STRAWN	10,674	1,857	51,075	-	485	47	102,700	-	-	166,838	6.9
42001165	COKE	-100.6900	32.0300	STRAWN	9,899	1,827	48,449	-	536	62	97,141	-	-	157,914	6.1
42001166	COKE	-100.6900	32.0300	STRAWN	9,828	1,730	48,537	-	490	0	96,939	-	-	157,523	5.1
42001167	COKE	-100.6900	32.0300	STRAWN	7,569	1,323	46,363	-	914	239	87,928	-	-	144,334	6.3
42001168	COKE	-100.7100	32.0200	STRAWN	7,903	1,450	48,055	-	920	163	91,563	-	-	150,054	7.1
42001169	COKE	-100.7100	32.0200	STRAWN	7,516	1,408	45,763	-	855	149	87,272	-	-	142,963	6.2
42001170	COKE	-100.7100	32.0200	STRAWN	7,696	1,543	48,952	-	963	156	92,821	-	-	152,129	7.0
42001171	COKE	-100.7100	32.0200	STRAWN	7,213	1,467	46,840	-	853	167	88,536	-	-	145,077	6.7
42001172	COKE	-100.7100	32.0200	STRAWN	8,424	1,503	48,949	-	862	123	94,082	-	-	153,944	7.4
42001173	COKE	-100.7100	32.0200	STRAWN	7,653	1,481	48,125	-	931	176	91,303	-	-	149,669	6.7
42001174	COKE	-100.7100	32.0200	STRAWN	7,773	2,334	44,123	-	1,079	215	87,667	-	-	143,190	7.0
42001175	COKE	-100.7100	32.0200	STRAWN	6,696	1,946	47,152	-	849	274	89,436	-	-	146,352	6.6
42001176	COKE	-100.7100	32.0200	STRAWN	7,897	1,451	48,260	-	911	191	91,840	-	-	150,550	6.8
42001177	COKE	-100.7100	32.0200	STRAWN	7,718	1,346	47,995	-	939	149	90,831	-	-	148,978	6.5
42001178	COKE	-100.7100	32.0200	STRAWN	7,772	1,485	47,563	-	1,124	224	90,487	-	-	148,656	6.7
42001179	COKE	-100.6800	32.0300	STRAWN	7,588	2,055	37,207	-	332	216	76,415	-	-	123,812	6.8
42001180	COKE	-100.6800	32.0300	STRAWN	10,536	1,888	52,815	-	485	0	105,253	-	-	170,976	5.2
42001181	COKE	-100.6800	32.0300	STRAWN	5,453	1,020	27,303	-	468	266	53,389	-	-	87,899	7.3

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42001182	COKE	-100.6800	32.0300	STRAWN	8,758	1,611	43,555	-	471	201	86,885	-	-	141,481	6.5
42001184	COKE	-100.6900	32.0300	STRAWN	8,917	1,685	48,427	-	682	157	92,831	-	-	152,698	6.5
42001185	COKE	-100.6900	32.0300	STRAWN	6,607	1,135	38,538	-	638	26	73,963	-	-	120,906	5.7
42001188	COKE	-100.6900	32.0300	STRAWN	6,308	1,136	38,509	-	773	175	73,201	-	-	120,103	6.7
42001189	COKE	-100.6900	32.0300	STRAWN	8,013	1,395	47,859	-	938	232	91,213	-	-	149,649	7.0
42001190	COKE	-100.7000	32.0300	STRAWN	5,110	1,422	34,836	-	1,002	285	65,993	-	-	108,647	7.2
42001191	COKE	-100.7000	32.0300	STRAWN	6,499	1,180	38,555	-	851	83	73,713	-	-	120,882	6.6
42001192	COKE	-100.7000	32.0300	STRAWN	9,629	1,774	48,414	-	427	97	96,519	-	-	156,861	6.1
42001193	COKE	-100.6800	32.0300	STRAWN	7,028	1,140	44,185	-	970	291	82,999	-	-	136,613	6.0
42001194	COKE	-100.6800	32.0300	STRAWN	7,052	1,386	45,720	-	1,052	258	86,091	-	-	141,559	7.0
42001195	COKE	-100.6800	32.0300	STRAWN	7,123	1,338	44,790	-	986	176	84,732	-	-	139,145	6.5
42001196	COKE	-100.6800	32.0300	STRAWN	7,682	1,381	46,292	-	934	161	88,213	-	-	144,663	6.3
42001197	COKE	-100.6800	32.0300	STRAWN	7,003	1,280	44,910	-	961	138	84,578	-	-	138,871	6.8
42001198	COKE	-100.7000	32.0400	STRAWN	7,016	1,383	45,880	-	1,049	225	86,286	-	-	141,839	7.1
42001199	COKE	-100.7000	32.0400	STRAWN	7,040	1,279	45,254	-	992	175	85,131	-	-	139,872	6.9
42001200	COKE	-100.7000	32.0400	STRAWN	7,171	1,145	44,036	-	934	66	83,231	-	-	136,583	6.3
42001201	COKE	-100.7000	32.0400	STRAWN	2,766	1,062	28,381	-	3,543	351	48,934	-	-	85,037	7.2
42001202	COKE	-100.7000	32.0400	STRAWN	5,412	549	39,022	-	2,056	199	69,714	-	-	116,951	6.6
42001203	COKE	-100.7000	32.0400	STRAWN	7,512	1,268	46,221	-	977	143	87,482	-	-	143,602	6.5
42001205	COKE	-100.7100	32.0400	STRAWN	7,384	1,271	46,078	-	1,012	221	86,970	-	-	142,936	6.9
42001206	COKE	-100.7100	32.0400	STRAWN	7,303	1,559	46,817	-	1,008	213	88,784	-	-	145,684	6.6
42001207	COKE	-100.7100	32.0400	STRAWN	7,614	1,141	46,989	-	1,152	248	88,254	-	-	145,397	6.9
42001208	COKE	-100.7200	32.0500	STRAWN	8,893	1,170	45,504	-	1,053	133	88,483	-	-	145,235	7.1
42001209	COKE	-100.7200	32.0500	STRAWN	8,567	1,473	42,124	-	287	116	84,127	-	-	136,693	6.3
42001210	COKE	-100.7200	32.0500	STRAWN	3,573	591	18,500	-	1,115	255	35,601	-	-	59,634	7.1
42001211	COKE	-100.7200	32.0500	STRAWN	3,511	653	18,253	-	1,105	84	35,401	-	-	59,008	7.4
42001212	COKE	-100.7200	32.0500	STRAWN	3,384	1,079	31,551	-	2,991	184	55,465	-	-	94,654	6.8
42001213	COKE	-100.6800	32.0600	STRAWN	3,883	809	19,101	-	600	194	38,130	-	-	62,718	6.5
42001214	COKE	-100.6800	32.0600	STRAWN	3,706	1,046	18,840	-	442	294	38,159	-	-	62,488	6.3
42001215	COKE	-100.6800	32.0600	STRAWN	13,378	1,625	40,063	-	919	25	89,496	-	-	145,507	5.2
42001217	COKE	-100.6900	32.0600	STRAWN	7,308	1,472	44,056	-	921	156	84,407	-	-	138,320	6.2
42001218	COKE	-100.6900	32.0600	STRAWN	6,618	1,252	42,811	-	945	196	80,554	-	-	132,375	6.9
42001219	COKE	-100.7100	32.0100	STRAWN	2,941	1,355	28,659	-	3,204	408	50,739	-	-	87,307	7.9
42001220	COKE	-100.7100	32.0100	STRAWN	2,745	1,002	23,559	-	6,032	671	40,798	-	-	72,757	7.1
42001221	COKE	-100.7100	32.0100	STRAWN	2,761	1,017	23,496	-	3,943	667	40,798	-	-	72,682	7.0
42001233	COKE	-100.7000	32.0100	STRAWN	7,818	1,322	48,353	-	974	155	91,430	-	-	150,051	6.4
42001234	COKE	-100.7000	32.0100	STRAWN	7,968	1,376	48,080	-	968	174	91,429	-	-	149,995	6.4
42001235	COKE	-100.7000	32.0100	STRAWN	8,436	1,499	51,463	-	1,030	24	97,880	-	-	160,333	5.6
42001236	COKE	-100.7000	32.0100	STRAWN	4,724	870	33,655	-	1,454	254	61,583	-	-	102,539	6.8
42001237	COKE	-100.7000	32.0100	STRAWN	7,533	1,434	41,507	-	600	177	80,964	-	-	132,216	7.1
42001238	COKE	-100.7000	32.0300	STRAWN	7,940	1,478	48,114	-	929	42	91,840	-	-	150,342	5.8
42001239	COKE	-100.7000	32.0300	STRAWN	7,414	1,226	47,018	-	1,089	229	88,253	-	-	145,229	7.0
42001240	COKE	-100.7000	32.0300	STRAWN	4,836	1,364	33,310	-	2,172	84	62,242	-	-	104,007	7.0
42001241	COKE	-100.7000	32.0300	STRAWN	12,820	1,988	54,452	-	56	230	111,959	-	-	181,843	6.6
42001247	COKE	-100.6800	32.0500	STRAWN	4,449	1,287	15,583	-	172	109	35,459	-	-	57,059	6.7
42001249	COKE	-100.6800	32.0500	STRAWN	11,367	2,116	51,973	-	331	48	106,143	-	-	171,978	5.6
42001250	COKE	-100.6600	32.0500	STRAWN	7,513	1,155	46,172	-	1,138	226	86,878	-	-	143,082	6.6
42001251	COKE	-100.6600	32.0500	STRAWN	6,913	1,180	42,956	-	874	-3	81,173	-	-	133,290	7.0
42001252	COKE	-100.6600	32.0500	STRAWN	7,266	1,463	43,894	-	976	175	84,007	-	-	137,782	6.1
42001253	COKE	-100.6600	32.0500	STRAWN	7,674	1,390	49,031	-	1,051	143	92,402	-	-	151,690	6.9
42001254	COKE	-100.6600	32.0500	STRAWN	8,133	2,185	46,440	-	1,029	123	91,562	-	-	149,472	7.6

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42001256	COKE	-100.6600	32.0500	STRAWN	7,180	1,319	46,635	-	997	197	87,634	-	-	143,962	6.7
42001257	COKE	-100.6800	32.0400	STRAWN	6,856	1,252	37,336	-	477	195	72,884	-	-	119,001	6.8
42001258	COKE	-100.6800	32.0400	STRAWN	7,937	1,512	45,419	-	786	78	87,884	-	-	143,616	6.1
42001259	COKE	-100.6800	32.0400	STRAWN	8,099	1,477	46,772	-	808	110	90,124	-	-	147,390	5.8
42001260	COKE	-100.6800	32.0400	STRAWN	12,635	2,145	55,419	-	412	31	113,771	-	-	184,414	7.1
42001261	COKE	-100.6800	32.0400	STRAWN	9,121	1,609	50,056	-	813	42	97,414	-	-	159,054	5.8
42001262	COKE	-100.6800	32.0400	STRAWN	8,494	1,504	47,813	-	800	92	92,522	-	-	151,226	6.3
42001263	COKE	-100.6800	32.0400	STRAWN	10,037	1,731	46,012	-	585	103	91,768	-	-	160,203	7.0
42001264	COKE	-100.6800	32.0400	STRAWN	10,472	1,765	48,803	-	1,042	50	98,156	-	-	160,287	6.4
42001265	COKE	-100.6800	32.0400	STRAWN	5,344	1,386	27,423	-	393	225	55,359	-	-	90,130	7.0
42001266	COKE	-100.6800	32.0400	STRAWN	2,575	540	13,483	-	299	240	26,559	-	-	43,694	7.2
42001267	COKE	-100.6800	32.0400	STRAWN	2,023	1,215	15,033	-	400	237	29,942	-	-	48,850	7.4
42001269	COKE	-100.6800	32.0600	STRAWN	12,340	1,977	51,582	-	691	58	108,181	-	-	175,725	5.7
42001270	COKE	-100.6800	32.0600	STRAWN	15,300	2,503	60,933	-	722	79	127,737	-	-	207,272	6.0
42001272	COKE	-100.6800	32.0400	STRAWN	6,343	1,253	36,854	-	601	167	71,159	-	-	116,377	6.7
42001273	COKE	-100.6800	32.0400	STRAWN	8,714	1,622	50,493	-	781	26	97,439	-	-	159,075	5.8
42001274	COKE	-100.6800	32.0400	STRAWN	12,008	2,098	52,057	-	465	63	107,214	-	-	173,882	6.5
42001275	COKE	-100.6800	32.0400	STRAWN	5,385	1,089	31,265	-	546	273	60,347	-	-	98,905	6.9
42001276	COKE	-100.6800	32.0400	STRAWN	4,908	1,155	31,204	-	721	235	59,495	-	-	97,718	7.2
42001277	COKE	-100.6800	32.0600	STRAWN	2,874	353	12,992	-	300	-1	25,929	-	-	42,447	5.0
42001278	COKE	-100.6800	32.0600	STRAWN	6,183	936	31,720	-	474	149	62,145	-	-	101,606	6.5
42001279	COKE	-100.6800	32.0600	STRAWN	2,037	451	10,604	-	324	333	20,835	-	-	34,585	6.9
42001280	COKE	-100.6800	32.0600	STRAWN	11,432	1,899	56,186	-	754	90	111,795	-	-	182,156	6.1
42001281	COKE	-100.6800	32.0600	STRAWN	9,127	1,494	45,335	-	580	52	89,954	-	-	146,543	5.9
42001282	COKE	-100.6900	32.0400	STRAWN	8,882	1,700	53,864	-	1,041	143	102,903	-	-	168,533	7.1
42001283	COKE	-100.6900	32.0400	STRAWN	7,709	1,372	46,416	-	899	129	88,491	-	-	145,016	5.7
42001284	COKE	-100.6900	32.0400	STRAWN	7,165	1,338	45,481	-	925	175	85,926	-	-	141,011	6.8
42001285	COKE	-100.6900	32.0400	STRAWN	8,604	1,450	45,513	-	756	161	89,003	-	-	145,487	6.8
42001286	COKE	-100.6900	32.0400	STRAWN	6,612	1,411	42,950	-	1,020	204	81,165	-	-	133,362	6.9
42001287	COKE	-100.6900	32.0400	STRAWN	7,474	1,446	45,239	-	893	189	86,453	-	-	141,695	6.3
42001288	COKE	-100.6900	32.0400	STRAWN	7,697	1,311	46,406	-	970	203	88,188	-	-	144,774	6.9
42001289	COKE	-100.6900	32.0400	STRAWN	8,036	1,398	47,087	-	929	169	91,239	-	-	148,858	6.5
42001290	COKE	-100.6900	32.0400	STRAWN	8,618	1,634	49,784	-	1,025	111	95,983	-	-	157,156	6.2
42001291	COKE	-100.6900	32.0400	STRAWN	7,907	1,939	47,714	-	906	130	90,893	-	-	148,940	6.4
42001292	COKE	-100.6900	32.0400	STRAWN	9,658	1,787	49,690	-	985	67	106,791	-	-	174,561	6.0
42001293	COKE	-100.6900	32.0400	STRAWN	7,269	1,271	41,205	-	748	131	79,384	-	-	120,148	6.5
42001294	COKE	-100.6900	32.0400	STRAWN	8,686	1,502	51,744	-	1,054	131	98,710	-	-	161,827	6.7
42001296	COKE	-100.6900	32.0400	STRAWN	7,613	1,360	47,100	-	970	171	89,242	-	-	146,455	6.8
42001297	COKE	-100.6900	32.0400	STRAWN	7,849	1,499	45,748	-	882	150	88,086	-	-	144,213	6.2
42001298	COKE	-100.6900	32.0400	STRAWN	8,556	1,503	49,945	-	970	104	95,785	-	-	156,863	6.2
42001299	COKE	-100.6900	32.0400	STRAWN	7,974	1,411	47,081	-	898	104	90,121	-	-	147,590	5.6
42001300	COKE	-100.6900	32.0400	STRAWN	8,012	1,380	46,507	-	897	118	89,207	-	-	146,121	6.9
42001301	COKE	-100.6900	32.0400	STRAWN	7,760	1,403	47,199	-	955	75	89,876	-	-	147,268	6.1
42001302	COKE	-100.6900	32.0400	STRAWN	9,497	1,670	56,197	-	980	38	107,608	-	-	175,988	5.6
42001303	COKE	-100.6900	32.0400	STRAWN	8,288	1,473	49,703	-	1,170	93	94,708	-	-	155,435	6.9
42001304	COKE	-100.6900	32.0400	STRAWN	7,833	1,319	46,764	-	1,048	62	89,029	-	-	146,055	6.0
42001305	COKE	-100.6900	32.0400	STRAWN	7,813	1,363	46,821	-	963	176	89,205	-	-	146,341	6.5
42001306	COKE	-100.6900	32.0400	STRAWN	7,616	1,307	46,656	-	968	247	88,394	-	-	145,188	6.8
42001307	COKE	-100.6900	32.0400	STRAWN	8,235	1,608	49,212	-	994	117	94,365	-	-	154,530	6.3
42001308	COKE	-100.6900	32.0400	STRAWN	7,832	1,872	44,823	-	765	156	87,772	-	-	143,219	6.7
42001309	COKE	-100.6900	32.0500	STRAWN	8,263	1,486	47,981	-	815	167	92,240	-	-	150,952	6.8

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42001310	COKE	-100.6900	32.0500	STRAWN	7,006	1,283	47,343	-	890	158	88,385	-	-	145,065	6.9
42001311	COKE	-100.6900	32.0500	STRAWN	7,834	1,584	44,119	-	864	235	85,731	-	-	140,367	6.7
42001312	COKE	-100.6900	32.0500	STRAWN	7,077	1,380	45,268	-	851	168	84,036	-	-	138,780	7.0
42001313	COKE	-100.6900	32.0500	STRAWN	7,575	1,313	46,015	-	1,061	220	87,272	-	-	143,455	7.0
42001315	COKE	-100.6900	32.0400	STRAWN	12,368	2,015	51,881	-	416	93	107,424	-	-	174,197	6.5
42001316	COKE	-100.6900	32.0400	STRAWN	9,027	1,748	51,510	-	693	84	99,960	-	-	163,022	6.4
42001317	COKE	-100.6900	32.0400	STRAWN	8,305	1,517	44,000	-	568	37	86,546	-	-	140,973	6.0
42001318	COKE	-100.6900	32.0400	STRAWN	10,695	2,369	51,383	-	447	7	104,753	-	-	169,654	5.4
42001319	COKE	-100.6900	32.0400	STRAWN	7,180	2,203	45,243	-	845	206	88,144	-	-	143,822	6.6
42001320	COKE	-100.6900	32.0400	STRAWN	7,014	1,458	44,674	-	980	190	84,710	-	-	139,025	7.1
42001321	COKE	-100.6900	32.0400	STRAWN	7,255	1,275	45,122	-	913	173	85,352	-	-	140,090	6.8
42001322	COKE	-100.6900	32.0400	STRAWN	7,242	1,523	46,459	-	869	201	88,132	-	-	144,425	6.6
42001323	COKE	-100.6900	32.0400	STRAWN	7,592	1,528	44,483	-	858	180	85,742	-	-	140,383	6.9
42001324	COKE	-100.6900	32.0400	STRAWN	8,909	1,652	51,879	-	925	6	99,894	-	-	163,264	5.4
42001325	COKE	-100.6900	32.0400	STRAWN	7,091	1,348	45,469	-	1,060	182	85,696	-	-	140,845	7.1
42001326	COKE	-100.6900	32.0500	STRAWN	7,185	1,207	45,081	-	954	216	84,910	-	-	139,553	7.2
42001327	COKE	-100.6900	32.0500	STRAWN	8,306	1,609	49,320	-	995	77	94,659	-	-	154,968	6.2
42001329	COKE	-100.6900	32.0500	STRAWN	7,374	1,214	45,938	-	1,077	236	86,486	-	-	142,326	7.0
42001330	COKE	-100.7000	32.0400	STRAWN	7,352	1,292	45,937	-	985	155	86,815	-	-	142,536	6.6
42001333	COKE	-100.7000	32.0400	STRAWN	7,041	1,446	45,195	-	983	176	85,529	-	-	140,370	6.9
42001334	COKE	-100.7000	32.0400	STRAWN	7,264	1,363	44,852	-	985	163	85,189	-	-	139,815	6.6
42001336	COKE	-100.7000	32.0400	STRAWN	7,552	1,178	46,837	-	1,162	165	88,058	-	-	144,952	7.0
42001338	COKE	-100.7000	32.0400	STRAWN	7,467	1,332	45,365	-	1,014	178	86,199	-	-	141,557	6.4
42001339	COKE	-100.7000	32.0400	STRAWN	6,932	1,334	45,534	-	1,022	153	85,523	-	-	141,040	6.8
42001340	COKE	-100.7000	32.0400	STRAWN	7,394	1,361	47,622	-	909	175	89,709	-	-	147,171	6.8
42001341	COKE	-100.7000	32.0400	STRAWN	7,454	1,155	46,460	-	1,078	221	87,268	-	-	143,636	7.0
42001345	COKE	-100.7200	32.0100	STRAWN	6,291	999	35,035	-	13	130	67,981	-	-	110,448	6.4
42001346	COKE	-100.7200	32.0100	STRAWN	2,202	434	16,523	-	31	217	30,493	-	-	49,900	6.8
42001348	COKE	-100.7200	32.0100	STRAWN	5,909	723	31,084	-	9	60	60,451	-	-	98,235	6.7
42001350	COKE	-100.7200	32.0100	STRAWN	5,460	1,407	33,603	-	728	65	65,001	-	-	106,264	6.6
42002523	COKE	-100.6800	32.0500	STRAWN	8,153	1,630	39,327	-	322	322	79,390	-	-	129,143	6.2
42002524	COKE	-100.6900	32.0400	STRAWN	7,551	1,293	46,749	-	889	131	88,479	-	-	145,091	6.5
42002525	COKE	-100.6900	32.0400	STRAWN	7,898	1,166	45,886	-	1,001	209	87,268	-	-	143,429	7.0
42002526	COKE	-100.6700	32.0400	STRAWN	14,213	2,377	49,254	-	280	90	107,759	-	-	173,974	6.5
42002527	COKE	-100.6700	32.0400	STRAWN	11,995	2,476	51,882	-	269	133	108,162	-	-	174,917	6.4
42002529	COKE	-100.6700	32.0400	STRAWN	7,180	1,907	37,737	-	1,332	152	75,376	-	-	123,684	7.0
42002530	COKE	-100.6700	32.0400	STRAWN	7,058	1,040	32,242	-	1,746	200	63,829	-	-	106,115	6.8
42002531	COKE	-100.6700	32.0400	STRAWN	13,487	2,584	57,181	-	163	63	119,408	-	-	192,886	6.1
42002532	COKE	-100.6700	32.0400	STRAWN	3,265	1,145	30,075	-	3,337	261	52,877	-	-	90,961	6.5
42002533	COKE	-100.6700	32.0500	STRAWN	10,219	1,716	43,892	-	199	132	90,536	-	-	146,693	6.3
42002534	COKE	-100.6700	32.0500	STRAWN	11,681	2,127	55,270	-	194	61	111,910	-	-	181,242	6.2
42002536	COKE	-100.6800	32.0400	STRAWN	6,520	1,445	34,139	-	356	195	68,011	-	-	110,667	6.7
42002537	COKE	-100.6700	32.0400	STRAWN	2,716	1,946	23,927	-	4,097	257	44,200	-	-	73,045	7.0
42002539	COKE	-100.6800	32.0400	STRAWN	3,957	2,005	20,376	-	369	242	43,849	-	-	70,798	6.9
42002540	COKE	-100.6800	32.0400	STRAWN	5,867	1,007	29,083	-	448	167	57,729	-	-	94,302	6.7
42002541	COKE	-100.6800	32.0400	STRAWN	6,652	1,119	33,633	-	550	165	66,389	-	-	108,508	7.0
42002542	COKE	-100.6800	32.0500	STRAWN	7,094	1,388	31,871	-	280	223	65,405	-	-	106,260	6.5
42002543	COKE	-100.6900	31.9200	STRAWN	6,398	1,624	33,643	-	146	92	67,767	-	-	109,669	6.6
42002544	COKE	-100.6900	31.9200	STRAWN	5,879	1,503	29,853	-	144	91	60,653	-	-	98,124	6.6
42002545	COKE	-100.6900	31.9200	STRAWN	6,251	1,516	30,863	-	150	91	62,898	-	-	101,770	6.7
42002547	COKE	-100.6900	31.9200	STRAWN	6,545	1,569	34,680	-	110	109	68,916	-	-	111,928	7.0

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42002549	COKE	-100.6900	31.9200	STRAWN	6,900	1,554	34,393	-	118	94	69,626	-	-	112,684	6.3
42002551	COKE	-100.6900	31.9200	STRAWN	6,804	1,521	33,029	-	118	140	67,236	-	-	109,279	6.7
42002552	COKE	-100.6800	31.9200	STRAWN	3,558	729	16,406	-	68	109	33,604	-	-	54,475	6.8
42002553	COKE	-100.6800	31.9200	STRAWN	3,899	830	19,439	-	89	162	39,129	-	-	63,548	7.1
42002557	COKE	-100.6800	31.9200	STRAWN	11,962	2,504	53,253	-	107	113	110,431	-	-	178,370	5.9
42002558	COKE	-100.6800	31.9200	STRAWN	1,848	408	8,428	-	5	71	17,408	-	-	28,169	7.0
42002560	COKE	-100.6800	31.9200	STRAWN	4,959	1,177	30,361	-	1,140	128	58,106	-	-	95,872	6.5
42002564	COKE	-100.6800	31.9100	STRAWN	11,144	2,148	48,812	-	128	105	101,082	-	-	163,819	6.4
42002565	COKE	-100.6800	31.9000	STRAWN	3,722	1,089	32,210	-	3,722	85	56,626	-	-	97,454	7.1
42002566	COKE	-100.6800	31.9000	STRAWN	3,839	1,090	31,813	-	3,299	152	56,500	-	-	93,393	6.8
42002567	COKE	-100.6800	31.9000	STRAWN	4,486	1,220	33,414	-	3,300	182	60,474	-	-	103,076	6.5
42002568	COKE	-100.6900	31.9000	STRAWN	1,800	372	8,706	-	87	66	17,595	-	-	28,631	7.0
42002570	COKE	-100.6900	31.9000	STRAWN	2,211	230	11,141	-	56	123	21,647	-	-	35,409	7.2
42002571	COKE	-100.6900	31.9000	STRAWN	3,539	667	17,545	-	125	137	35,088	-	-	57,100	6.5
42002572	COKE	-100.6900	31.9000	STRAWN	2,430	527	12,477	-	83	111	24,948	-	-	40,576	6.6
42002573	COKE	-100.6900	31.9000	STRAWN	1,989	423	10,222	-	55	111	20,410	-	-	33,211	6.7
42002574	COKE	-100.6800	31.9100	STRAWN	5,358	1,091	25,072	-	201	111	51,107	-	-	82,940	6.5
42002575	COKE	-100.6800	31.9100	STRAWN	4,478	1,435	23,722	-	195	100	48,483	-	-	78,412	6.4
42002576	COKE	-100.6800	31.9100	STRAWN	4,321	1,044	22,102	-	199	126	44,551	-	-	72,344	6.7
42002577	COKE	-100.6800	31.9100	STRAWN	5,739	1,056	17,122	-	180	125	53,458	-	-	77,680	6.6
42002578	COKE	-100.6800	31.9100	STRAWN	7,859	1,419	35,257	-	141	43	72,269	-	-	116,988	6.1
42002580	COKE	-100.6800	31.9100	STRAWN	6,205	1,218	30,390	-	160	91	61,218	-	-	101,417	6.9
42002581	COKE	-100.6800	31.9100	STRAWN	2,621	703	14,321	-	150	26	28,642	-	-	46,462	5.4
42002582	COKE	-100.6800	31.9100	STRAWN	2,733	607	14,583	-	135	162	28,901	-	-	47,121	7.2
42002583	COKE	-100.6800	31.9100	STRAWN	2,840	607	14,100	-	139	239	28,294	-	-	46,219	6.7
42002584	COKE	-100.7400	31.9900	STRAWN	276	48	2,664	-	403	216	3,691	-	-	7,297	7.1
42002585	COKE	-100.7300	31.9900	STRAWN	2,785	450	18,423	-	180	238	31,749	-	-	53,825	7.0
42002586	COKE	-100.7300	32.0000	STRAWN	6,354	1,234	36,135	-	8	119	70,485	-	-	114,334	6.3
42002587	COKE	-100.7300	32.0000	STRAWN	4,201	750	25,331	-	11	187	48,559	-	-	79,039	6.3
42002588	COKE	-100.7300	32.0000	STRAWN	3,541	636	20,034	-	15	85	38,951	-	-	63,260	6.0
42002589	COKE	-100.6900	32.0700	STRAWN	7,196	1,322	48,080	-	997	276	89,830	-	-	147,701	7.1
42002590	COKE	-100.6900	32.0700	STRAWN	7,259	1,503	48,869	-	782	140	91,916	-	-	150,469	6.9
42002591	COKE	-100.6900	32.0700	STRAWN	3,165	984	27,536	-	4,001	182	47,869	-	-	83,737	6.0
42002592	COKE	-100.6900	31.9000	STRAWN	6,423	1,119	36,978	-	808	145	70,967	-	-	116,440	6.3
42002593	COKE	-100.7300	32.0100	STRAWN	5,623	801	27,002	-	56	59	53,843	-	-	87,383	7.3
42002594	COKE	-100.7500	31.9700	STRAWN	6,051	2,238	32,318	-	1,790	181	65,635	-	-	108,213	6.5
42002600	COKE	-100.7000	32.0200	STRAWN	7,741	915	43,005	-	800	204	73,940	-	-	127,261	6.9
42002601	COKE	-100.7000	32.0200	STRAWN	7,113	1,276	43,500	-	960	219	82,541	-	-	135,609	7.0
42002602	COKE	-100.7000	32.0200	STRAWN	7,464	1,659	47,530	-	924	212	90,522	-	-	148,311	6.7
42002603	COKE	-100.7000	32.0200	STRAWN	7,252	1,344	46,167	-	928	159	87,156	-	-	143,006	6.6
42002604	COKE	-100.7000	32.0200	STRAWN	6,191	1,374	39,917	-	1,006	204	75,645	-	-	124,337	7.0
42002605	COKE	-100.7000	32.0200	STRAWN	6,854	2,080	46,770	-	887	225	89,518	-	-	146,334	6.7
42002607	COKE	-100.7000	32.0100	STRAWN	10,440	1,852	42,374	-	348	162	88,857	-	-	144,033	6.4
42002608	COKE	-100.7000	32.0100	STRAWN	8,038	2,341	42,268	-	527	156	85,737	-	-	139,067	6.9
42002609	COKE	-100.7000	32.0100	STRAWN	6,112	1,641	35,917	-	720	201	70,330	-	-	114,921	7.1
42002610	COKE	-100.7000	32.0100	STRAWN	8,586	1,561	49,518	-	517	146	95,628	-	-	155,956	6.5
42002611	COKE	-100.7000	32.0200	STRAWN	3,085	656	18,147	-	680	307	34,674	-	-	57,549	7.4
42002612	COKE	-100.7000	32.0200	STRAWN	6,044	1,276	39,470	-	892	246	74,476	-	-	122,404	7.0
42002613	COKE	-100.7000	32.0200	STRAWN	5,425	1,213	35,319	-	764	297	66,859	-	-	109,879	6.8
42002614	COKE	-100.7000	32.0100	STRAWN	4,849	924	29,214	-	833	261	55,551	-	-	91,632	7.2
42002615	COKE	-100.7000	32.0200	STRAWN	4,468	887	27,391	-	770	266	52,006	-	-	85,788	7.2

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42002616	COKE	-100.7000	32.0200	STRAWN	5,803	1,215	38,799	-	747	248	72,936	-	-	119,748	6.9
42002617	COKE	-100.7000	32.0200	STRAWN	6,629	1,285	43,130	-	772	218	81,282	-	-	133,316	6.3
42002618	COKE	-100.7000	32.0200	STRAWN	6,282	1,486	41,391	-	842	218	78,518	-	-	128,739	6.3
42002620	COKE	-100.7000	32.0200	STRAWN	5,290	1,069	32,407	-	839	286	61,661	-	-	101,553	6.7
42002621	COKE	-100.6900	32.0200	STRAWN	4,448	947	24,464	-	719	254	47,673	-	-	78,506	7.2
42002795	COKE	-100.7200	32.0000	STRAWN	10,281	1,746	55,002	-	92	37	107,999	-	-	175,155	5.1
42002796	COKE	-100.7200	32.0000	STRAWN	11,301	1,808	55,665	-	89	116	110,966	-	-	179,943	6.4
42002797	COKE	-100.7100	32.0100	STRAWN	6,976	1,536	47,463	-	891	200	89,228	-	-	146,294	6.8
42002799	COKE	-100.7100	32.0100	STRAWN	8,280	1,463	46,660	-	928	245	90,029	-	-	147,605	6.6
42002820	COKE	-100.5700	31.9800	STRAWN	8,953	1,508	52,397	-	900	300	99,498	-	-	164,516	6.2
42002823	COKE	-100.7100	32.0400	STRAWN	11,505	2,105	50,836	-	78	89	104,767	-	-	169,380	5.7
42002824	COKE	-100.7100	32.0400	STRAWN	8,850	1,035	39,226	-	304	60	78,903	-	-	128,378	6.0
42002825	COKE	-100.7100	32.0400	STRAWN	3,106	468	14,813	-	832	155	28,996	-	-	48,370	7.9
42002827	COKE	-100.7100	32.0400	STRAWN	3,341	1,165	26,611	-	3,189	279	47,825	-	-	82,409	6.6
42002828	COKE	-100.7000	32.0400	STRAWN	7,654	1,154	46,251	-	1,099	236	87,272	-	-	143,666	7.0
42002829	COKE	-100.7000	32.0300	STRAWN	6,575	1,396	45,952	-	958	268	85,695	-	-	140,844	7.2
42002830	COKE	-100.7000	32.0300	STRAWN	6,917	1,309	45,088	-	1,004	176	84,731	-	-	139,224	6.9
42002831	COKE	-100.7000	32.0300	STRAWN	4,725	924	30,988	-	929	320	58,115	-	-	96,002	7.3
42002833	COKE	-100.6900	32.0200	STRAWN	5,103	1,100	30,569	-	2,422	133	57,502	-	-	96,829	6.0
42002834	COKE	-100.7200	32.0100	STRAWN	5,236	1,098	38,843	-	1,693	145	68,628	-	-	115,644	6.9
42002835	COKE	-100.7000	32.0300	STRAWN	6,330	1,080	39,337	-	1,058	212	74,073	-	-	122,089	7.2
42002836	COKE	-100.7000	32.0300	STRAWN	5,560	2,266	42,074	-	869	238	80,540	-	-	131,546	6.8
42002837	COKE	-100.7000	32.0300	STRAWN	7,383	1,956	45,510	-	899	237	88,134	-	-	144,119	6.8
42002838	COKE	-100.7000	32.0300	STRAWN	6,977	1,296	45,386	-	904	139	85,353	-	-	140,055	6.4
42002839	COKE	-100.7100	32.0200	STRAWN	2,634	1,002	25,780	-	3,137	182	44,915	-	-	77,650	6.8
42002840	COKE	-100.7100	32.0200	STRAWN	2,772	967	25,957	-	3,546	198	45,011	-	-	78,451	7.3
42002841	COKE	-100.6900	32.0300	STRAWN	5,520	2,709	42,097	-	879	250	81,774	-	-	133,229	6.4
42002842	COKE	-100.6900	32.0300	STRAWN	7,037	1,238	45,677	-	943	173	85,693	-	-	140,761	6.4
42002843	COKE	-100.6900	32.0300	STRAWN	7,174	1,267	44,319	-	1,158	240	83,724	-	-	137,881	7.1
42002845	COKE	-100.7100	32.0300	STRAWN	8,097	1,214	47,566	-	977	105	90,423	-	-	148,383	6.2
42002846	COKE	-100.7100	32.0300	STRAWN	8,210	1,685	48,018	-	530	144	93,002	-	-	151,589	6.1
42002847	COKE	-100.6900	32.0300	STRAWN	8,116	1,493	46,499	-	650	165	89,830	-	-	146,753	6.7
42002848	COKE	-100.6800	32.0300	STRAWN	10,981	1,970	51,085	-	340	112	103,621	-	-	168,108	6.5
42002850	COKE	-100.7100	32.0200	STRAWN	2,910	732	23,532	-	4,000	75	40,572	-	-	71,820	7.0
42002851	COKE	-100.7100	32.0200	STRAWN	8,414	1,122	47,775	-	939	199	91,013	-	-	149,462	7.0
42002852	COKE	-100.7200	32.0100	STRAWN	1,395	552	33,974	-	3,367	376	53,760	-	-	93,424	6.9
42002853	COKE	-100.6900	32.0600	STRAWN	1,357	229	7,719	-	620	371	14,299	-	-	24,596	7.3
42002854	COKE	-100.6900	32.0600	STRAWN	7,303	2,229	21,926	-	707	291	52,538	-	-	84,993	6.9
42002856	COKE	-100.6900	32.0600	STRAWN	8,415	1,362	46,315	-	728	171	89,635	-	-	146,627	6.6
42002857	COKE	-100.6900	32.0600	STRAWN	6,064	1,131	37,529	-	832	207	71,158	-	-	116,920	6.8
42002858	COKE	-100.6900	32.0500	STRAWN	6,783	1,500	41,139	-	1,281	88	78,807	-	-	129,598	6.5
42002859	COKE	-100.6900	32.0500	STRAWN	5,900	1,260	36,558	-	1,920	152	68,975	-	-	114,764	6.7
42002860	COKE	-100.6900	32.0500	STRAWN	5,510	1,033	31,305	-	1,599	175	59,751	-	-	99,373	6.8
42003043	COKE	-100.6800	31.9300	STRAWN	3,037	723	14,343	-	57	124	29,482	-	-	47,765	6.4
42003044	COKE	-100.6800	31.9300	STRAWN	4,277	869	20,919	-	47	162	42,226	-	-	69,023	6.8
42003046	COKE	-100.6800	31.9300	STRAWN	6,240	1,161	30,003	-	75	81	60,587	-	-	98,147	6.6
42003051	COKE	-100.6700	31.9000	STRAWN	3,494	1,186	31,557	-	2,820	36	56,193	-	-	95,286	6.3
42005114	COKE	-100.6900	31.9200	STRAWN	10,376	2,590	53,113	-	141	56	107,662	-	-	173,938	6.3
42005115	COKE	-100.6900	31.9200	STRAWN	11,622	3,130	54,301	-	138	63	113,276	-	-	182,531	6.0
42005116	COKE	-100.6800	31.9200	STRAWN	3,702	832	18,268	-	95	156	36,982	-	-	60,035	6.9
42005118	COKE	-100.7100	32.0300	STRAWN	7,682	1,302	46,065	-	1,038	169	87,579	-	-	143,834	6.7

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42005119	COKE	-100.6800	31.9200	STRAWN	1,618	417	8,012	-	10	87	16,380	-	-	26,523	7.2
42006820	COKE	-100.7700	32.0000	STRAWN	7,682	1,512	46,953	-	822	176	89,716	-	-	146,860	6.0
42006821	COKE	-100.7700	32.0000	STRAWN	7,639	1,429	45,122	-	780	137	86,604	-	-	141,710	5.8
42006822	COKE	-100.7700	32.0000	STRAWN	7,332	1,275	46,745	-	863	100	88,071	-	-	144,385	6.7
42006823	COKE	-100.7700	32.0000	STRAWN	6,838	1,311	39,644	-	652	364	76,784	-	-	126,063	6.4
42006824	COKE	-100.7700	32.0000	STRAWN	7,891	1,350	47,725	-	952	156	90,720	-	-	148,794	6.0
42006826	COKE	-100.7700	32.0000	STRAWN	6,975	1,442	45,874	-	900	195	86,499	-	-	141,886	6.8
42006827	COKE	-100.7700	32.0000	STRAWN	6,534	1,144	42,156	-	1,008	262	78,998	-	-	130,102	7.2
42006828	COKE	-100.7700	32.0000	STRAWN	7,184	1,401	46,003	-	893	150	86,981	-	-	142,612	7.5
42006829	COKE	-100.7700	32.0000	STRAWN	7,507	1,436	46,050	-	891	182	87,710	-	-	143,775	7.1
42006830	COKE	-100.7700	32.0000	STRAWN	7,703	1,459	46,753	-	824	143	89,307	-	-	146,188	6.6
42006831	COKE	-100.7700	32.0000	STRAWN	7,335	1,044	44,119	-	1,249	186	83,022	-	-	136,957	6.2
42006832	COKE	-100.7700	32.0000	STRAWN	7,224	1,381	44,103	-	964	202	84,008	-	-	137,882	6.5
42007208	COKE	-100.7700	32.0000	STRAWN	7,335	1,215	50,232	-	858	185	93,230	-	-	153,248	6.6
42007448	COKE	-100.7700	32.0000	STRAWN	13,804	1,993	50,484	-	236	28	107,882	-	-	174,428	5.9
42007449	COKE	-100.7700	32.0000	STRAWN	7,250	1,288	45,727	-	861	161	86,358	-	-	141,646	7.3
42007450	COKE	-100.7700	32.0000	STRAWN	5,803	1,051	39,024	-	843	216	72,754	-	-	119,692	6.7
42007451	COKE	-100.7700	32.0000	STRAWN	5,551	1,739	34,281	-	829	269	66,979	-	-	109,649	7.2
42007452	COKE	-100.7700	32.0000	STRAWN	7,528	1,411	41,668	-	871	207	80,922	-	-	132,606	6.6
42007453	COKE	-100.7700	32.0000	STRAWN	8,182	1,495	43,490	-	808	190	85,186	-	-	139,350	6.6
42007454	COKE	-100.7700	32.0000	STRAWN	5,853	1,312	41,850	-	751	250	78,011	-	-	128,028	7.1
42007455	COKE	-100.7700	32.0000	STRAWN	6,487	2,105	40,010	-	820	200	78,585	-	-	128,207	6.8
42007456	COKE	-100.7700	32.0000	STRAWN	6,934	1,107	42,811	-	878	184	80,748	-	-	132,661	6.7
42007457	COKE	-100.7700	32.0000	STRAWN	6,455	1,207	41,107	-	820	201	77,603	-	-	127,393	6.8
42007458	COKE	-100.7700	32.0000	STRAWN	3,005	1,452	27,428	-	4,378	90	48,559	-	-	84,911	7.1
42007459	COKE	-	-	STRAWN	6,577	1,158	40,404	-	743	240	76,629	-	-	125,751	7.1
42007460	COKE	-100.7700	32.0000	STRAWN	7,928	1,563	48,683	-	592	44	93,182	-	-	151,993	5.5
42007461	COKE	-100.7700	32.0000	STRAWN	8,074	1,451	48,347	-	669	146	92,486	-	-	151,174	6.1
42007462	COKE	-	-	STRAWN	4,953	936	31,276	-	754	240	59,024	-	-	97,184	7.5
42007463	COKE	-100.7700	32.0000	STRAWN	6,854	1,535	45,628	-	728	146	86,331	-	-	141,222	6.6
42007464	COKE	-100.7700	32.0000	STRAWN	7,884	1,557	48,181	-	704	142	92,175	-	-	150,643	7.6
42007465	COKE	-100.7700	32.0000	STRAWN	6,894	1,097	44,664	-	747	231	83,574	-	-	137,207	6.7
42007466	COKE	-100.7700	32.0000	STRAWN	3,645	535	22,952	-	650	299	42,747	-	-	70,828	7.4
42007468	COKE	-100.7700	32.0000	STRAWN	6,758	1,455	44,142	-	737	158	83,625	-	-	136,874	6.8
42007469	COKE	-100.7700	32.0000	STRAWN	3,249	1,009	30,198	-	4,779	64	51,693	-	-	90,992	6.8
42007470	COKE	-100.7700	32.0000	STRAWN	5,997	2,513	40,559	-	642	188	79,894	-	-	129,793	6.4
42007471	COKE	-100.7700	32.0000	STRAWN	2,159	448	21,580	-	522	334	37,824	-	-	62,866	7.4
42007472	COKE	-100.7700	32.0000	STRAWN	7,335	1,346	45,174	-	733	151	85,925	-	-	140,665	6.6
42007473	COKE	-100.7700	32.0000	STRAWN	8,793	1,547	42,274	-	704	218	84,603	-	-	138,139	6.7
42007476	COKE	-100.7700	32.0000	STRAWN	7,322	1,377	46,629	-	795	179	88,171	-	-	144,473	6.4
42007477	COKE	-100.7700	32.0000	STRAWN	7,986	1,534	44,863	-	776	139	87,118	-	-	142,416	7.0
42007478	COKE	-100.7700	32.0000	STRAWN	6,649	1,271	44,356	-	821	176	83,155	-	-	136,427	6.4
42007479	COKE	-	-	STRAWN	6,942	2,111	42,972	-	910	264	83,874	-	-	137,073	7.1
42007480	COKE	-100.7700	32.0000	STRAWN	7,599	1,447	46,897	-	818	155	89,309	-	-	146,225	-
42007481	COKE	-100.7700	32.0000	STRAWN	7,135	1,296	47,336	-	897	195	88,612	-	-	145,472	6.5
42007482	COKE	-100.7700	32.0000	STRAWN	7,630	1,770	47,538	-	867	236	91,183	-	-	149,224	6.5
42007483	COKE	-100.7700	32.0000	STRAWN	8,818	972	34,476	-	259	157	71,312	-	-	115,994	6.6
42007484	COKE	-100.7700	32.0000	STRAWN	8,315	1,179	43,842	-	757	143	85,105	-	-	139,340	6.9
42007485	COKE	-100.7700	32.0000	STRAWN	6,376	1,116	40,761	-	648	147	76,824	-	-	125,872	6.9
42007486	COKE	-100.7700	32.0000	STRAWN	12,346	1,727	53,831	-	399	101	109,530	-	-	177,935	6.6
42007487	COKE	-100.7700	32.0000	STRAWN	11,361	1,300	55,456	-	451	163	108,973	-	-	177,704	6.0

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42007488	COKE	-100.7700	32.0000	STRAWN	12,049	1,938	51,808	-	500	96	106,424	-	-	172,815	5.8
42007490	COKE	-100.7700	32.0000	STRAWN	7,511	1,465	45,959	-	697	135	87,830	-	-	143,598	6.7
42007492	COKE	-100.7700	32.0000	STRAWN	6,164	1,309	39,326	-	859	224	74,592	-	-	122,473	6.1
42007493	COKE	-100.7700	32.0000	STRAWN	1,762	245	10,654	-	521	312	19,699	-	-	33,194	7.5
42007494	COKE	-100.7700	32.0000	STRAWN	5,426	916	34,189	-	756	221	64,296	-	-	105,804	6.7
42007495	COKE	-100.7700	32.0000	STRAWN	7,645	1,316	46,513	-	988	231	88,246	-	-	144,939	-
42007496	COKE	-100.7700	32.0000	STRAWN	3,590	1,003	21,377	-	514	297	41,685	-	-	68,465	7.0
42007498	COKE	-100.7700	32.0000	STRAWN	6,812	2,104	31,109	-	372	188	65,773	-	-	106,359	6.4
42007499	COKE	-	-	STRAWN	7,465	1,634	32,797	-	347	224	68,160	-	-	110,628	6.4
42007500	COKE	-100.7700	32.0000	STRAWN	9,607	1,882	44,225	-	378	132	90,315	-	-	146,539	6.4
42007501	COKE	-100.7700	32.0000	STRAWN	7,016	1,406	43,960	-	761	240	83,590	-	-	136,973	5.9
42007503	COKE	-100.7700	32.0000	STRAWN	5,248	877	33,207	-	872	268	62,253	-	-	102,725	7.3
42007504	COKE	-100.7700	32.0000	STRAWN	6,474	1,284	43,498	-	725	194	81,616	-	-	133,790	6.7
42007506	COKE	-100.7700	32.0000	STRAWN	11,652	1,734	49,812	-	706	182	101,851	-	-	165,937	6.2
42007507	COKE	-100.7700	32.0000	STRAWN	6,568	2,228	44,825	-	940	243	86,400	-	-	141,204	6.8
42007508	COKE	-100.7700	32.0000	STRAWN	6,813	1,188	45,949	-	915	291	85,519	-	-	140,675	6.5
42007509	COKE	-100.7700	32.0000	STRAWN	5,610	1,336	38,129	-	1,026	249	66,175	-	-	118,059	7.0
42007510	COKE	-100.7700	32.0000	STRAWN	7,212	1,320	46,286	-	931	167	87,193	-	-	143,109	6.9
42007511	COKE	-100.7700	32.0000	STRAWN	6,965	1,432	46,736	-	937	157	85,739	-	-	141,966	7.6
42007512	COKE	-100.7700	32.0000	STRAWN	7,038	1,330	46,938	-	913	217	87,904	-	-	144,339	6.8
42007514	COKE	-100.7700	32.0000	STRAWN	5,569	1,725	26,268	-	181	213	55,130	-	-	89,087	7.0
42007515	COKE	-100.7700	32.0000	STRAWN	4,692	912	27,036	-	530	218	52,131	-	-	85,199	7.2
42007516	COKE	-100.7700	32.0000	STRAWN	6,859	1,238	32,278	-	167	166	65,294	-	-	106,002	6.4
42007517	COKE	-100.7700	32.0000	STRAWN	7,548	1,337	34,780	-	157	107	70,700	-	-	114,628	6.7
42007518	COKE	-100.7700	32.0000	STRAWN	5,141	2,278	20,776	-	157	200	47,544	-	-	76,096	6.7
42007519	COKE	-100.7700	32.0000	STRAWN	7,624	1,408	37,161	-	282	122	74,608	-	-	121,205	6.7
42007520	COKE	-100.7700	32.0000	STRAWN	8,226	1,508	44,920	-	758	246	87,513	-	-	143,171	6.7
42007521	COKE	-100.7700	32.0000	STRAWN	7,303	1,882	44,711	-	835	182	86,625	-	-	141,538	6.3
42007522	COKE	-100.7700	32.0000	STRAWN	6,691	1,240	41,807	-	900	104	79,192	-	-	129,934	6.9
42007523	COKE	-100.7700	32.0000	STRAWN	7,871	1,495	44,901	-	760	156	86,864	-	-	142,048	6.6
42007524	COKE	-100.7700	32.0000	STRAWN	7,140	1,361	46,195	-	726	159	87,204	-	-	142,785	6.4
42007525	COKE	-100.7700	32.0000	STRAWN	6,486	1,981	41,890	-	773	134	81,196	-	-	132,460	6.7
42007526	COKE	-100.7700	32.0000	STRAWN	6,173	1,121	38,005	-	740	244	72,101	-	-	118,382	7.0
42007528	COKE	-100.7700	32.0000	STRAWN	7,668	1,559	42,547	-	665	127	83,155	-	-	135,721	6.7
42007529	COKE	-100.7700	32.0000	STRAWN	7,203	1,389	45,640	-	697	151	86,567	-	-	141,645	7.4
42007530	COKE	-100.7700	32.0000	STRAWN	6,275	1,261	35,739	-	653	190	69,296	-	-	113,413	6.7
42007532	COKE	-100.7700	32.0000	STRAWN	5,711	1,733	34,053	-	576	261	67,088	-	-	109,421	6.9
42007533	COKE	-100.7700	32.0000	STRAWN	5,933	1,287	38,876	-	658	235	73,568	-	-	120,557	6.7
42007534	COKE	-100.7700	32.0000	STRAWN	7,310	1,459	39,949	-	642	167	78,218	-	-	127,744	6.7
42007536	COKE	-100.7700	32.0000	STRAWN	6,772	1,585	44,599	-	739	176	84,724	-	-	138,595	6.8
42007537	COKE	-100.7700	32.0000	STRAWN	5,691	1,237	35,403	-	760	232	67,570	-	-	110,894	6.9
42007538	COKE	-100.7700	32.0000	STRAWN	6,487	1,535	41,943	-	691	212	80,113	-	-	130,980	6.8
42007539	COKE	-100.7700	32.0000	STRAWN	6,284	1,872	37,295	-	165	-3	73,955	-	-	119,571	7.0
42007544	COKE	-100.7700	32.0000	STRAWN	6,549	1,274	42,248	-	650	234	79,831	-	-	130,786	6.5
42007545	COKE	-100.7700	32.0000	STRAWN	7,617	1,265	45,116	-	979	198	85,894	-	-	141,069	6.4
42007546	COKE	-100.6900	31.9200	STRAWN	3,362	765	18,035	-	141	57	35,847	-	-	58,207	6.7
42007554	COKE	-100.7700	32.0000	STRAWN	1,943	207	14,037	-	33	262	25,511	-	-	41,994	6.8
42007555	COKE	-100.7700	32.0000	STRAWN	1,935	439	16,566	-	44	46	30,186	-	-	49,216	6.0
42007556	COKE	-100.7700	32.0000	STRAWN	12,687	1,894	63,702	-	80	154	126,046	-	-	204,564	6.1
42007557	COKE	-100.7700	32.0000	STRAWN	5,176	739	25,691	-	35	102	50,842	-	-	82,585	6.5
42007559	COKE	-100.7700	32.0000	STRAWN	4,923	924	36,206	-	1,666	27	65,984	-	-	109,730	7.5

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42009574	COKE	-100.7700	32.0000	STRAWN	14,212	1,620	62,174	-	3	13	125,979	-	-	204,310	5.4
42018249	COKE	-100.7700	32.0000	STRAWN	7,349	1,403	45,634	-	990	162	86,657	-	-	142,195	6.2
42018250	COKE	-100.7700	32.0000	STRAWN	14,893	2,159	55,904	-	33	85	118,803	-	-	191,878	6.6
42018251	COKE	-100.7700	32.0000	STRAWN	9,473	1,390	46,276	-	816	182	91,455	-	-	149,592	6.5
42018252	COKE	-100.7700	32.0000	STRAWN	10,565	2,690	47,853	-	919	91	74,392	-	-	136,511	6.2
42018253	COKE	-100.7700	32.0000	STRAWN	12,053	1,840	53,316	-	38	40	108,878	-	-	176,166	5.7
42018263	COKE	-	-	STRAWN	12,474	2,989	54,708	-	385	31	111,567	-	-	181,031	5.2
42105424	COKE	-100.7700	32.0000	STRAWN	11,475	2,048	-	-	765	170	137,250	-	-	224,101	5.7
42251008	COKE	-100.7000	32.0100	STRAWN	14,423	2,918	56,115	-	23	78	120,568	-	-	194,238	5.4
42251081	COKE	-100.6700	32.0700	STRAWN	2,786	909	23,451	-	3,575	251	42,590	-	-	74,637	6.8
42251295	COKE	-100.7100	32.0100	STRAWN	742	243	4,970	-	83	246	9,494	-	-	15,788	7.5
42251296	COKE	-100.7000	32.0100	STRAWN	6,329	1,151	42,447	-	762	239	79,357	-	-	130,286	6.5
42251297	COKE	-100.7000	32.0100	STRAWN	5,473	1,479	40,049	-	658	246	75,025	-	-	122,931	6.7
42251298	COKE	-100.7000	32.0100	STRAWN	6,209	1,344	38,251	-	907	183	73,035	-	-	119,935	6.1
42251299	COKE	-100.7000	32.0100	STRAWN	5,472	1,086	34,833	-	630	203	66,011	-	-	108,236	7.1
42251301	COKE	-100.7000	32.0200	STRAWN	5,364	1,061	34,197	-	700	192	67,750	-	-	109,265	6.8
42251302	COKE	-100.7000	32.0200	STRAWN	7,005	1,227	43,760	-	1,302	159	85,988	-	-	139,442	6.6
42251303	COKE	-100.7100	32.0100	STRAWN	6,207	1,631	40,875	-	848	200	78,054	-	-	127,815	6.6
42251304	COKE	-100.7100	32.0100	STRAWN	4,917	1,310	35,107	-	636	215	66,026	-	-	108,210	6.7
42251305	COKE	-100.7000	32.0100	STRAWN	4,829	899	30,920	-	611	193	58,215	-	-	95,667	6.5
42251306	COKE	-100.6900	32.0200	STRAWN	4,356	1,004	29,112	-	761	164	54,825	-	-	90,222	6.3
42251307	COKE	-100.6900	32.0200	STRAWN	1,074	209	6,224	-	347	417	11,556	-	-	19,827	7.2
42251309	COKE	-100.7000	32.0200	STRAWN	1,707	318	9,895	-	548	306	19,548	-	-	32,322	6.7
42251310	COKE	-100.7000	32.0200	STRAWN	1,498	324	10,296	-	678	306	19,674	-	-	32,778	7.1
42251311	COKE	-100.7000	32.0200	STRAWN	2,676	486	18,128	-	483	291	33,578	-	-	55,649	6.5
42251316	COKE	-100.7200	31.9700	STRAWN	11,749	2,429	56,264	-	0	173	115,240	-	-	186,331	5.8
42254257	COKE	-100.7700	32.0000	STRAWN	3,700	634	20,904	-	617	174	40,136	-	-	66,175	6.1
42254259	COKE	-100.7700	32.0000	STRAWN	1,541	406	9,544	-	346	283	18,170	-	-	30,291	7.3
42254263	COKE	-100.7700	32.0000	STRAWN	3,747	696	17,386	-	288	222	35,189	-	-	57,530	7.1
42254265	COKE	-100.7700	32.0000	STRAWN	5,372	1,271	35,746	-	623	181	67,940	-	-	111,134	6.9
42254268	COKE	-100.7700	32.0000	STRAWN	4,541	899	24,975	-	406	229	48,686	-	-	79,736	7.9
42254271	COKE	-100.7700	32.0000	STRAWN	2,687	355	15,816	-	692	283	29,460	-	-	49,293	7.1
42254273	COKE	-100.7700	32.0000	STRAWN	5,425	731	24,752	-	600	215	49,327	-	-	81,050	7.2
42254274	COKE	-100.7700	32.0000	STRAWN	5,006	859	32,129	-	763	200	60,201	-	-	99,158	7.0
42254275	COKE	-100.7700	32.0000	STRAWN	3,584	891	24,386	-	563	246	46,038	-	-	75,709	7.2
42254276	COKE	-100.7700	32.0000	STRAWN	3,610	745	24,138	-	560	212	45,233	-	-	74,500	6.7
42254280	COKE	-100.7700	32.0000	STRAWN	2,494	560	17,919	-	1,421	7	32,940	-	-	55,661	5.6
42254288	COKE	-100.7700	32.0000	STRAWN	1,106	208	7,187	-	359	342	13,196	-	-	22,399	7.5
42254290	COKE	-100.7700	32.0000	STRAWN	6,280	1,265	43,398	-	1,243	255	80,690	-	-	133,131	6.7
42254292	COKE	-100.7700	32.0000	STRAWN	6,354	2,053	44,659	-	1,157	238	85,059	-	-	139,521	6.3
42254295	COKE	-100.7700	32.0000	STRAWN	5,463	1,116	34,456	-	561	185	65,585	-	-	107,376	7.0
42254296	COKE	-100.7700	32.0000	STRAWN	4,513	887	30,338	-	774	281	56,631	-	-	93,425	6.7
42254298	COKE	-100.7700	32.0000	STRAWN	12,157	1,875	61,468	-	0	112	121,573	-	-	197,364	5.8
42254315	COKE	-100.7700	32.0000	STRAWN	5,473	1,028	33,768	-	725	233	67,107	-	-	108,335	6.6
42254318	COKE	-100.7700	32.0000	STRAWN	2,845	394	14,795	-	164	166	28,762	-	-	47,132	6.7
42254320	COKE	-100.7700	32.0000	STRAWN	2,156	463	14,302	-	260	139	26,945	-	-	44,266	6.2
42254321	COKE	-100.7700	32.0000	STRAWN	3,419	1,529	27,394	-	2,676	7	50,754	-	-	85,780	5.2
42254322	COKE	-100.7700	32.0000	STRAWN	3,644	672	23,698	-	38	0	43,157	-	-	70,605	5.2
42254350	COKE	-100.7700	32.0000	STRAWN	4,418	977	35,282	-	2,552	239	62,950	-	-	106,422	7.4
42254351	COKE	-100.7700	32.0000	STRAWN	6,573	1,345	45,393	-	934	232	84,660	-	-	139,146	6.2
42254353	COKE	-100.7700	32.0000	STRAWN	7,562	1,029	46,264	-	930	184	86,920	-	-	142,890	7.1

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42254354	COKE	-100.7700	32.0000	STRAWN	7,601	1,111	48,510	-	962	239	90,640	-	-	149,068	7.1
42254357	COKE	-100.7700	32.0000	STRAWN	5,158	1,209	37,232	-	1,155	188	68,961	-	-	113,903	6.9
42254365	COKE	-100.7700	32.0000	STRAWN	3,746	875	22,016	-	2,075	255	43,927	-	-	72,895	7.0
42255013	COKE	-100.7700	32.0000	STRAWN	4,121	786	22,230	-	352	163	43,517	-	-	71,170	7.2
42255414	COKE	-100.6200	32.0200	STRAWN	7,532	1,297	45,051	-	1,033	162	85,716	-	-	140,791	6.3
42255420	COKE	-100.6500	32.0200	STRAWN	10,261	1,224	38,869	-	1,016	24	80,898	-	-	132,293	5.0
42250990	GLASSCOCK	-101.4500	32.0800	-	2,320	899	23,812	-	2,998	1,080	40,600	-	-	71,709	8.0
42250991	GLASSCOCK	-101.4600	32.0700	-	2,050	894	23,861	-	1,901	1,153	40,950	-	-	70,809	7.3
42000384	GLASSCOCK	-101.4000	31.8500	CLEAR FORK	2,546	825	31,798	-	2,926	711	53,608	-	-	92,571	7.8
42000942	GLASSCOCK	-101.7400	31.7100	CLEAR FORK	2,310	745	33,293	-	4,984	310	54,000	-	-	95,744	7.6
42000943	GLASSCOCK	-101.7400	31.7100	CLEAR FORK	2,130	793	33,145	-	4,835	612	53,400	-	-	94,915	8.0
42000385	GLASSCOCK	-101.4000	31.8500	ELLENBERGER	1,803	311	16,607	-	1,486	688	28,451	-	-	49,502	7.4
42000386	GLASSCOCK	-101.4200	31.8000	FUSSELMAN	1,795	507	19,687	-	1,500	591	34,241	-	-	59,076	7.0
42000388	GLASSCOCK	-101.6800	31.6800	FUSSELMAN	3,286	316	43,576	-	258	258	73,784	-	-	125,015	6.5
42105584	GLASSCOCK	-	-	FUSSELMAN	3,237	776	-3	-	1,278	211	51,546	-	-	85,803	6.1
42105585	GLASSCOCK	-	-	FUSSELMAN	4,155	1,468	25,968	-	2,162	422	51,728	-	-	85,903	6.2
42002762	GLASSCOCK	-101.4500	32.0800	GRAYBURG	3,432	1,390	20,143	-	2,972	821	38,513	-	-	67,271	6.2
42256079	GLASSCOCK	-101.4600	32.0700	GRAYBURG	2,111	821	23,370	-	1,753	1,454	40,025	-	-	69,535	6.3
42255711	GLASSCOCK	-101.4500	32.0800	PERMIAN	2,510	833	23,524	-	2,971	1,098	40,310	-	-	71,246	6.7
42255712	GLASSCOCK	-101.4500	32.0800	PERMIAN	2,290	808	22,668	-	3,240	1,086	38,337	-	-	68,429	6.6
42000138	GLASSCOCK	-101.4600	32.0800	SAN ANDRES	2,792	1,042	25,374	-	1,976	942	45,111	-	-	77,236	6.6
42000139	GLASSCOCK	-101.4600	32.0800	SAN ANDRES	2,766	982	26,066	-	2,044	916	45,923	-	-	78,803	6.9
42001359	GLASSCOCK	-101.4600	32.0700	SAN ANDRES	2,226	940	21,882	-	1,283	1,332	38,710	-	-	66,373	6.9
42001360	GLASSCOCK	-101.4600	32.0700	SAN ANDRES	1,110	499	11,070	-	4,741	703	16,580	-	-	34,703	6.8
42001367	GLASSCOCK	-101.4500	32.0800	SAN ANDRES	2,279	761	22,369	-	3,108	1,127	37,792	-	-	67,436	6.6
42002802	GLASSCOCK	-101.4500	32.0800	SAN ANDRES	1,585	640	21,969	-	1,026	527	37,478	-	-	63,224	7.9
42105311	GLASSCOCK	-101.4800	31.9700	SAN ANDRES	2,160	7,630	7,751	-	-3	-3	38,000	-	-	55,541	6.5
42105312	GLASSCOCK	-101.4700	32.0700	SAN ANDRES	1,684	1,015	-3	-	1,748	1,454	38,013	-	-	66,133	6.7
42000941	GLASSCOCK	-101.7400	31.7100	SPRABERRY	2,900	572	83,345	-	171	317	135,000	-	-	222,305	6.4
42002003	HOWARD	-101.2600	32.2700	-	288	89	312	-	670	442	500	-	-	2,302	7.7
42002347	HOWARD	-101.3400	32.0900	-	3,045	1,006	30,515	-	2,658	270	53,310	-	-	90,827	-
42003123	HOWARD	-101.3300	32.0900	-	3,196	1,129	29,412	-	2,846	616	51,859	-	-	89,058	-
42005039	HOWARD	-101.2600	32.1100	-	1,092	914	18,234	-	4,864	775	28,367	-	-	54,516	-
42005042	HOWARD	-101.4400	32.0900	-	1,573	589	29,989	-	3,471	470	47,870	-	-	84,010	-
42014402	HOWARD	-	-	-	3,041	995	-3	-	2,209	740	51,374	-	-	87,695	-
42019284	HOWARD	-	-	-	2,370	973	31,257	-	405	669	54,552	-	-	90,227	-
42019285	HOWARD	-	-	-	3,315	1,061	30,436	-	2,999	518	53,235	-	-	91,451	-
42252852	HOWARD	-101.2600	32.1100	-	1,570	510	3,252	-	409	197	8,863	-	-	14,802	6.9
42252881	HOWARD	-101.2600	32.1100	-	2,385	863	22,186	-	2,437	913	38,643	-	-	67,430	6.7
42252882	HOWARD	-101.2600	32.1100	-	2,239	972	22,190	-	2,386	913	38,651	-	-	67,352	6.6
42252888	HOWARD	-101.2600	32.1100	-	2,682	1,030	26,508	-	2,957	654	46,046	-	-	79,877	7.1
42018922	HOWARD	-101.3100	32.4600	CANYON	4,520	690	65,918	-	1,276	258	110,600	-	-	183,262	6.7
42251856	HOWARD	-101.3600	32.5200	CANYON	3,076	710	31,938	-	1,671	383	55,359	-	-	93,225	6.8
42251860	HOWARD	-101.3400	32.5200	CANYON	3,524	1,093	34,285	-	2,807	534	60,106	-	-	102,438	6.7
42251861	HOWARD	-101.3400	32.5200	CANYON	3,770	1,243	33,421	-	2,785	483	59,452	-	-	101,156	6.1
42251863	HOWARD	-101.3400	32.5100	CANYON	2,997	909	29,376	-	1,518	354	54,631	-	-	89,787	6.9
42251866	HOWARD	-101.3400	32.5100	CANYON	2,852	996	30,974	-	1,575	349	54,497	-	-	91,335	7.1
42018926	HOWARD	-101.2300	32.4600	CANYON LOWER PENNSYLVANIA	3,400	1,235	30,749	-	3,222	662	54,360	-	-	93,628	7.3
42003344	HOWARD	-101.2500	32.4700	CANYON PENNSYLVANIAN	3,440	725	35,005	-	1,528	235	60,960	-	-	101,893	7.1

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42018925	HOWARD	-101.3100	32.4600	CANYON PENNSYLVANIAN	3,500	645	34,996	-	1,534	280	60,480	-	-	101,235	6.9
42015409	HOWARD	-101.5300	32.4800	CANYON REEF	4,986	1,209	41,815	-	1,019	95	75,968	-	-	125,093	6.8
42015410	HOWARD	-	-	CANYON REEF	10,339	1,267	73,219	-	618	69	134,306	-	-	219,819	5.3
42105327	HOWARD	-101.5000	32.5200	CANYON REEF	3,672	919	-3	-	1,642	435	73,440	-	-	122,740	7.5
42105595	HOWARD	-	-	CANYON REEF	3,291	1,509	-3	-	2,405	608	58,236	-	-	98,332	6.0
42251854	HOWARD	-101.3500	32.5100	CANYON REEF	3,139	688	31,293	-	1,650	307	54,391	-	-	91,481	5.8
42251855	HOWARD	-101.3500	32.5100	CANYON REEF	3,015	826	31,642	-	1,662	427	55,081	-	-	92,745	6.9
42251857	HOWARD	-101.3600	32.5200	CANYON REEF	3,114	722	32,105	-	1,589	349	55,677	-	-	93,556	7.6
42251858	HOWARD	-101.3500	32.5100	CANYON REEF	3,126	676	34,150	-	1,515	404	58,696	-	-	98,569	7.7
42251859	HOWARD	-101.3500	32.5200	CANYON REEF	3,408	897	39,357	-	2,138	396	67,662	-	-	113,869	7.2
42251862	HOWARD	-101.3400	32.5200	CANYON REEF	3,544	1,185	34,267	-	2,754	623	60,314	-	-	102,695	6.9
42251864	HOWARD	-101.3400	32.5100	CANYON REEF	2,905	683	32,245	-	1,650	413	55,338	-	-	93,235	7.4
42251865	HOWARD	-101.3400	32.5100	CANYON REEF	3,358	745	34,551	-	1,455	378	60,010	-	-	100,497	7.7
42251867	HOWARD	-101.3400	32.5200	CANYON REEF	2,810	797	32,251	-	1,650	400	55,562	-	-	93,470	7.2
42251868	HOWARD	-101.3400	32.5200	CANYON REEF	2,884	697	32,680	-	1,575	337	56,206	-	-	94,381	7.6
42251869	HOWARD	-101.3500	32.5100	CANYON REEF	3,532	753	35,005	-	1,402	361	61,233	-	-	102,286	7.0
42000270	HOWARD	-101.2400	32.2700	CHINLE	540	232	5,486	-	3,281	100	7,565	-	-	17,313	-
42000273	HOWARD	-101.2600	32.2900	CLEAR FORK	3,424	1,612	33,500	-	3,136	174	60,323	-	-	102,645	8.4
42000274	HOWARD	-101.2600	32.2900	CLEAR FORK	3,103	1,226	28,403	-	3,544	322	50,693	-	-	88,010	-
42000637	HOWARD	-101.3600	32.0900	CLEAR FORK	3,170	953	28,487	-	3,080	353	49,920	-	-	85,963	7.3
42002305	HOWARD	-101.2800	32.1000	CLEAR FORK	3,248	813	28,434	-	3,208	887	49,132	-	-	85,770	-
42002632	HOWARD	-101.3600	32.0900	CLEAR FORK	2,748	945	26,560	-	2,201	732	46,520	-	-	79,706	6.7
42002634	HOWARD	-101.3600	32.0900	CLEAR FORK	2,710	897	26,720	-	3,243	695	45,813	-	-	80,078	7.0
42005104	HOWARD	-101.1900	32.2800	CLEAR FORK	2,868	1,026	29,268	-	2,835	29	51,138	-	-	87,183	6.0
42014400	HOWARD	-	-	CLEAR FORK	6,914	3,444	-3	-	2,204	157	66,914	-	-	109,686	6.3
42014401	HOWARD	-	-	CLEAR FORK	3,219	1,807	-3	-	2,452	120	61,691	-	-	103,431	7.9
42014403	HOWARD	-	-	CLEAR FORK	2,905	896	-3	-	2,244	716	52,749	-	-	90,023	6.3
42105326	HOWARD	-101.2400	32.1300	CLEAR FORK	3,766	1,913	-3	-	2,311	301	67,196	-	-	115,601	7.3
42251853	HOWARD	-101.2400	32.2400	CLEAR FORK	3,314	773	29,120	-	2,891	869	50,298	-	-	87,265	7.2
42251874	HOWARD	-101.2200	32.2500	CLEAR FORK	1,251	213	4,339	-	2,442	878	7,224	-	-	16,347	7.7
42251875	HOWARD	-101.2100	32.2700	CLEAR FORK	1,314	285	5,521	-	2,113	654	9,718	-	-	19,606	7.9
42252880	HOWARD	-101.2600	32.1100	CLEAR FORK	2,985	895	28,053	-	2,795	608	48,696	-	-	84,031	7.8
42255616	HOWARD	-101.2400	32.2600	CLEAR FORK	1,164	222	4,271	-	2,824	490	6,954	-	-	15,953	7.6
42255628	HOWARD	-101.2300	32.2500	CLEAR FORK	1,911	929	17,968	-	3,355	371	31,054	-	-	55,587	6.9
42255629	HOWARD	-101.4800	32.4800	DEVONIAN-SILURIAN	1,850	424	21,615	-	1,779	406	36,293	-	-	62,365	6.7
42018927	HOWARD	-	-	ELLENBURGER	2,260	518	17,238	-	1,416	511	30,780	-	-	52,718	7.2
42018928	HOWARD	-	-	ELLENBURGER	1,750	382	16,031	-	1,295	179	27,900	-	-	47,532	8.0
42015412	HOWARD	-101.4000	32.3300	FUSSELMAN	2,219	430	23,865	-	1,505	137	40,761	-	-	68,916	6.7
42015413	HOWARD	-101.4000	32.3300	FUSSELMAN	2,112	399	24,012	-	1,691	383	40,429	-	-	69,026	7.0
42015411	HOWARD	-101.4700	32.4400	FUSSELMAN	2,474	454	40,642	-	927	135	67,561	-	-	112,194	6.0
42002623	HOWARD	-101.3600	32.0900	SILURO DEVONIAN GLORIETA	2,464	487	22,586	-	3,120	374	38,085	-	-	67,116	7.6
42002629	HOWARD	-101.3600	32.0900	GLORIETA	2,734	1,129	25,311	-	3,675	517	44,144	-	-	77,509	7.3
42002631	HOWARD	-101.3600	32.0900	GLORIETA	2,682	951	26,518	-	2,906	598	45,911	-	-	79,566	6.7
42002635	HOWARD	-101.3600	32.0900	GLORIETA	2,722	983	26,997	-	2,962	582	46,784	-	-	81,029	6.7
42018921	HOWARD	-101.1900	32.4800	GLORIETA	3,230	91	30,508	-	2,941	677	53,520	-	-	91,988	7.5
42251832	HOWARD	-101.3500	32.1000	GLORIETA	3,404	996	30,336	-	1,665	672	54,096	-	-	91,239	7.3
42251834	HOWARD	-101.3400	32.0900	GLORIETA	3,026	887	28,145	-	3,121	771	48,461	-	-	84,412	6.9
42251849	HOWARD	-101.3300	32.1000	GLORIETA	2,759	885	26,747	-	1,980	695	46,200	-	-	79,950	7.4

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42252884	HOWARD	-101.2600	32.1100	GLORIETA	2,932	848	29,011	-	2,456	708	50,081	-	-	86,038	7.0
42255600	HOWARD	-101.3400	32.0900	GLORIETA	2,759	870	25,171	-	3,128	664	43,497	-	-	76,089	8.1
42255602	HOWARD	-101.3600	32.1000	GLORIETA	2,932	962	28,799	-	2,213	673	50,399	-	-	85,980	6.8
42255604	HOWARD	-101.3400	32.0900	GLORIETA	2,817	885	25,958	-	2,860	691	45,163	-	-	78,374	7.9
42255605	HOWARD	-101.3300	32.0900	GLORIETA	2,922	972	26,274	-	2,923	805	45,901	-	-	79,798	8.2
42255607	HOWARD	-101.3600	32.0900	GLORIETA	2,307	1,346	28,892	-	3,802	444	49,368	-	-	86,265	7.6
42255613	HOWARD	-101.3600	32.0900	GLORIETA	2,570	913	27,892	-	2,751	631	47,816	-	-	82,573	7.0
42003375	HOWARD	-101.1900	32.4900	GLORIETA PERMIAN	4,290	872	39,418	-	1,198	122	70,000	-	-	115,900	6.7
42003376	HOWARD	-101.1800	32.4800	GLORIETA PERMIAN	3,180	1,099	29,693	-	2,970	736	52,080	-	-	89,758	7.7
42018923	HOWARD	-101.1900	32.4800	GLORIETA PERMIAN	3,360	1,184	23,251	-	3,136	539	42,720	-	-	74,190	7.6
42019328	HOWARD	-101.1900	32.4800	GLORIETA PERMIAN	3,170	1,106	29,859	-	2,903	848	52,320	-	-	90,206	7.4
42252856	HOWARD	-101.2600	32.1100	GLORIETA-SAN ANDRES	2,696	988	25,071	-	3,065	737	43,611	-	-	76,169	7.5
42252858	HOWARD	-101.2600	32.1100	GLORIETA-SAN ANDRES	2,893	964	26,925	-	3,009	647	46,776	-	-	81,216	7.5
42252859	HOWARD	-101.2600	32.1100	GLORIETA-SAN ANDRES	2,628	1,119	26,390	-	3,040	773	45,919	-	-	79,869	7.6
42252865	HOWARD	-101.2600	32.1100	GLORIETA-SAN ANDRES	2,392	1,170	25,718	-	3,078	666	44,584	-	-	77,608	7.5
42001670	HOWARD	-101.4600	32.0900	GRAYBURG	2,646	982	24,618	-	1,500	926	43,856	-	-	74,527	6.7
42001671	HOWARD	-101.4500	32.0900	GRAYBURG	3,044	1,019	12,108	-	1,300	805	25,598	-	-	43,873	6.7
42001676	HOWARD	-101.4500	32.0900	GRAYBURG	2,771	887	21,029	-	1,850	506	38,253	-	-	65,296	6.5
42001678	HOWARD	-101.4500	32.0900	GRAYBURG	2,646	751	8,675	-	1,640	680	18,644	-	-	33,035	6.6
42002304	HOWARD	-101.2800	32.0900	GRAYBURG	5,480	3,711	56,614	-	2,363	195	106,047	-	-	174,497	-
42002627	HOWARD	-101.3600	32.0900	GRAYBURG	2,416	919	25,460	-	3,056	946	43,408	-	-	76,205	7.8
42251004	HOWARD	-101.4600	32.0800	GRAYBURG	2,957	694	23,271	-	3,664	856	41,600	-	-	73,985	7.7
42252843	HOWARD	-101.2600	32.1100	GRAYBURG	2,121	747	21,580	-	2,491	1,135	36,702	-	-	64,776	8.3
42252845	HOWARD	-101.2600	32.1100	GRAYBURG	1,202	617	17,616	-	2,913	1,070	28,313	-	-	51,732	7.1
42252847	HOWARD	-101.2600	32.1100	GRAYBURG	1,795	727	21,532	-	3,222	1,043	35,513	-	-	63,834	7.0
42252849	HOWARD	-101.2600	32.1100	GRAYBURG	2,279	940	25,114	-	1,994	1,123	43,371	-	-	74,821	7.6
42252851	HOWARD	-101.2600	32.1100	GRAYBURG	2,226	1,202	23,373	-	3,239	877	40,582	-	-	71,500	6.7
42252869	HOWARD	-101.2600	32.1100	GRAYBURG	2,331	958	26,122	-	1,874	991	45,235	-	-	77,510	8.0
42252874	HOWARD	-101.2600	32.1100	GRAYBURG	1,826	714	20,189	-	3,999	899	32,967	-	-	60,594	6.8
42002309	HOWARD	-101.2900	32.0900	GRAYBURG CLEARFORK	3,291	975	30,052	-	3,100	899	52,250	-	-	90,603	-
42000636	HOWARD	-101.3600	32.0900	GRAYBURG SAN ANDRES	605	223	3,623	-	750	163	6,680	-	-	12,044	8.2
42255603	HOWARD	-101.3400	32.0900	GRAYBURG-SAN ANDRES	3,419	1,020	25,435	-	2,892	842	45,488	-	-	79,096	6.6
42255632	HOWARD	-101.3600	32.0900	GRAYBURG-SAN ANDRES	3,184	1,057	30,359	-	2,990	430	53,070	-	-	91,090	7.3
42255633	HOWARD	-101.3600	32.0900	GRAYBURG-SAN ANDRES	3,065	1,086	31,118	-	3,091	497	53,998	-	-	92,855	6.9
42252853	HOWARD	-101.2600	32.1100	OGALLALA	2,260	547	2,910	-	94	146	9,930	-	-	15,887	7.5
42015415	HOWARD	-101.5700	32.5100	PENNSYLVANIAN	4,979	950	45,061	-	1,105	291	80,026	-	-	132,412	6.9
42018924	HOWARD	-	-	PENNSYLVANIAN	3,420	1,324	34,845	-	3,131	584	61,080	-	-	104,384	7.3
42105322	HOWARD	-101.5700	32.4900	PENNSYLVANIAN	4,142	954	-3	-	872	306	76,736	-	-	126,757	6.0
42105323	HOWARD	-101.5800	32.5000	PENNSYLVANIAN	4,209	870	-3	-	1,183	318	76,384	-	-	126,716	5.7
42105591	HOWARD	-101.6200	32.4200	PENNSYLVANIAN	10,805	2,096	-3	-	1,022	221	140,286	-	-	229,630	6.3
42009261	HOWARD	-101.5200	32.5200	PENNSYLVANIAN REEF	3,198	1,183	39,020	-	1,201	281	68,245	-	-	113,128	7.0

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42009262	HOWARD	-101.1900	32.4800	PENNSYLVANIAN REEF	4,498	1,074	38,482	-	855	165	69,755	-	-	114,830	6.2
42105592	HOWARD	-101.2300	32.4600	PENNSYLVANIAN REEF	4,708	1,102	40,369	-	1,793	145	73,872	-	-	121,988	6.5
42000268	HOWARD	-101.2300	32.2900	PERMIAN	2,902	1,503	32,961	-	3,372	273	57,693	-	-	98,703	7.8
42000269	HOWARD	-101.2100	32.2800	PERMIAN	4,053	2,043	41,078	-	3,654	263	73,579	-	-	124,646	7.6
42002628	HOWARD	-101.3600	32.0900	PERMIAN	4,080	1,896	28,328	-	2,339	512	54,405	-	-	91,560	-
42007185	HOWARD	-	-	PERMIAN	2,936	3,276	71,069	-	4,477	88	121,020	-	-	202,866	-
42007233	HOWARD	-101.4000	32.3300	PERMIAN	3,900	1,140	34,024	-	3,192	1,315	59,590	-	-	103,161	-
42007235	HOWARD	-101.4000	32.3300	PERMIAN	792	301	5,157	-		537	7,607	-	-	-3	-
42007311	HOWARD	-101.2600	32.1100	PERMIAN	3,530	1,302	24,340	-	2,486	851	45,259	-	-	77,768	6.8
42252844	HOWARD	-101.2600	32.1100	PERMIAN	2,514	921	25,020	-	1,793	1,099	43,765	-	-	75,111	6.5
42000271	HOWARD	-101.2600	32.2900	QUEEN	6,401	14,919	115,223	-	2,396	37	230,673	-	-	371,725	-
42105324	HOWARD	-101.2600	32.1200	QUEEN	2,808	2,533	-3	-	2,797	335	89,954	-	-	150,201	6.8
42000013	HOWARD	-101.1800	32.4600	SAN ANDRES	9,206	3,470	25,659	-	1,891	589	64,244	-	-	105,059	7.2
42001635	HOWARD	-101.2000	32.2900	SAN ANDRES	2,500	14,800	90,425	-	1,980	51	213,389	-	-	335,085	6.7
42001666	HOWARD	-101.4600	32.0800	SAN ANDRES	2,589	884	18,700	-	1,520	686	34,401	-	-	60,361	8.2
42001667	HOWARD	-101.4600	32.0800	SAN ANDRES	2,590	885	18,700	-	1,520	686	34,400	-	-	58,781	8.2
42001668	HOWARD	-101.4600	32.0900	SAN ANDRES	2,560	758	21,900	-	1,830	759	38,700	-	-	66,507	7.8
42001672	HOWARD	-101.4500	32.0900	SAN ANDRES	2,699	697	13,700	-	1,969	515	26,200	-	-	45,829	8.4
42001675	HOWARD	-101.4500	32.0900	SAN ANDRES	2,840	820	20,300	-	1,300	493	37,400	-	-	63,152	7.9
42001677	HOWARD	-101.4500	32.0900	SAN ANDRES	2,799	699	11,300	-	2,110	464	22,600	-	-	39,972	8.1
42001680	HOWARD	-101.4500	32.0900	SAN ANDRES	2,630	719	12,800	-	1,880	556	24,800	-	-	43,384	8.1
42002350	HOWARD	-101.3400	32.0900	SAN ANDRES	2,508	841	22,859	-	3,058	634	39,554	-	-	69,398	-
42002633	HOWARD	-101.3600	32.0900	SAN ANDRES	3,217	925	31,200	-	3,023	679	53,873	-	-	92,917	6.6
42002636	HOWARD	-101.4600	32.0900	SAN ANDRES	2,879	1,095	27,140	-	1,758	853	48,342	-	-	82,067	5.9
42005041	HOWARD	-101.4000	32.1000	SAN ANDRES	3,176	1,131	32,732	-	3,402	281	56,734	-	-	97,456	-
42005068	HOWARD	-101.4000	32.1000	SAN ANDRES	3,145	1,135	30,994	-	3,331	262	54,075	-	-	92,942	-
42007181	HOWARD	-101.2600	32.1100	SAN ANDRES	4,120	2,304	53,636	-	1,800	249	95,500	-	-	155,809	7.6
42007182	HOWARD	-101.2600	32.1100	SAN ANDRES	4,080	2,160	58,788	-	1,700	234	103,000	-	-	169,962	7.4
42007222	HOWARD	-101.2600	32.1100	SAN ANDRES	4,440	2,112	52,555	-	1,500	234	94,000	-	-	154,841	7.6
42007234	HOWARD	-	-	SAN ANDRES	1,844	1,083	19,256	-	4,665	210	32,561	-	-	59,620	-
42009264	HOWARD	-101.1900	32.4800	SAN ANDRES	3,285	1,135	21,785	-	2,240	758	55,019	-	-	84,222	7.3
42009265	HOWARD	-101.2600	32.1100	SAN ANDRES	3,226	163	27,296	-	2,603	1,141	45,917	-	-	80,346	7.2
42015408	HOWARD	-101.2600	32.1100	SAN ANDRES	3,538	1,157	31,334	-	3,487	182	55,235	-	-	94,933	7.7
42105321	HOWARD	-101.2300	32.2300	SAN ANDRES	2,996	1,051	-3	-	2,532	338	44,732	-	-	76,574	6.8
42105325	HOWARD	-101.2400	32.2300	SAN ANDRES	3,453	537	-3	-	2,359	946	43,805	-	-	75,997	6.6
42105467	HOWARD	-	-	SAN ANDRES	3,115	1,476	-3	-	2,924	585	55,484	-	-	94,793	6.6
42105593	HOWARD	-	-	SAN ANDRES	10,943	1,695	-3	-	2,267	356	82,840	-	-	137,015	6.7
42105594	HOWARD	-	-	SAN ANDRES	10,507	2,900	-3	-	1,962	342	85,892	-	-	141,062	6.9
42106011	HOWARD	-	-	SAN ANDRES	2,767	4,291	30,746	-	3,322	279	62,219	-	-	103,639	7.8
42106042	HOWARD	-	-	SAN ANDRES	4,612	1,539	24,951	-	2,697	619	48,787	-	-	83,205	7.4
42251003	HOWARD	-101.4500	32.0900	SAN ANDRES	3,795	1,630	26,948	-	1,303	1,026	51,463	-	-	86,166	6.5
42251827	HOWARD	-101.3500	32.0900	SAN ANDRES	3,253	1,050	30,724	-	3,094	566	53,447	-	-	92,134	7.4
42251828	HOWARD	-101.3400	32.0900	SAN ANDRES	4,036	1,719	31,289	-	2,627	373	58,307	-	-	98,358	5.5
42251829	HOWARD	-101.3500	32.1000	SAN ANDRES	2,783	1,234	27,201	-	2,541	660	51,766	-	-	86,185	6.5
42251830	HOWARD	-101.3500	32.1000	SAN ANDRES	3,485	1,094	29,006	-	2,401	744	51,850	-	-	88,581	6.4
42251831	HOWARD	-101.3400	32.1000	SAN ANDRES	8,316	1,762	41,802	-	207	173	83,167	-	-	136,444	6.5
42251833	HOWARD	-101.3500	32.0900	SAN ANDRES	3,004	990	29,828	-	2,134	629	52,226	-	-	88,811	6.6
42251835	HOWARD	-101.3300	32.1000	SAN ANDRES	2,888	1,020	27,407	-	3,048	564	47,831	-	-	82,759	7.5
42251836	HOWARD	-101.3300	32.1000	SAN ANDRES	2,850	996	25,968	-	3,410	605	45,074	-	-	78,903	8.0

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42251837	HOWARD	-101.3300	32.0900	SAN ANDRES	3,113	1,235	25,860	-	3,135	761	46,336	-	-	80,441	6.8
42251838	HOWARD	-101.3400	32.1000	SAN ANDRES	2,758	947	24,981	-	4,000	744	43,228	-	-	77,161	7.4
42251839	HOWARD	-101.3400	32.1000	SAN ANDRES	2,559	848	22,959	-	3,410	119	41,533	-	-	71,834	7.3
42251843	HOWARD	-101.3300	32.1000	SAN ANDRES	2,661	1,316	24,535	-	4,225	689	43,121	-	-	76,841	7.7
42251844	HOWARD	-101.3300	32.1000	SAN ANDRES	2,735	985	25,780	-	4,412	720	43,787	-	-	78,419	7.2
42251845	HOWARD	-101.3300	32.1000	SAN ANDRES	2,685	1,051	25,473	-	4,000	581	44,287	-	-	78,616	7.3
42251847	HOWARD	-101.3300	32.0900	SAN ANDRES	3,313	1,151	28,199	-	4,549	809	49,128	-	-	87,432	7.9
42251848	HOWARD	-101.3300	32.0900	SAN ANDRES	3,312	909	25,586	-	3,375	561	45,390	-	-	79,406	8.2
42251872	HOWARD	-101.2200	32.2500	SAN ANDRES	878	128	3,561	-	1,110	1,271	5,851	-	-	12,799	6.4
42251873	HOWARD	-101.2300	32.2600	SAN ANDRES	2,138	394	13,155	-	4,116	520	21,878	-	-	42,200	7.3
42252838	HOWARD	-101.2600	32.1100	SAN ANDRES	2,420	1,006	23,975	-	4,045	548	41,320	-	-	73,807	7.6
42252840	HOWARD	-101.2600	32.1100	SAN ANDRES	2,801	1,040	28,012	-	2,875	830	48,548	-	-	84,110	7.4
42252848	HOWARD	-101.2600	32.1100	SAN ANDRES	2,634	1,014	25,229	-	1,903	1,014	44,521	-	-	76,316	5.6
42252857	HOWARD	-101.2600	32.1100	SAN ANDRES	3,745	761	29,983	-	3,105	649	52,390	-	-	90,664	6.9
42252861	HOWARD	-101.2600	32.1100	SAN ANDRES	2,531	763	22,284	-	2,333	1,010	38,814	-	-	67,735	8.2
42252862	HOWARD	-101.2600	32.1100	SAN ANDRES	2,689	875	23,739	-	2,931	764	41,281	-	-	72,278	8.0
42252863	HOWARD	-101.2600	32.1100	SAN ANDRES	2,016	607	22,045	-	3,970	839	35,941	-	-	65,419	8.0
42252868	HOWARD	-101.2400	32.2000	SAN ANDRES	2,215	573	37,915	-	4,949	107	60,344	-	-	106,103	7.2
42252871	HOWARD	-101.2600	32.1100	SAN ANDRES	3,293	587	23,995	-	2,350	90	43,193	-	-	74,003	7.0
42252872	HOWARD	-101.2600	32.1100	SAN ANDRES	2,776	775	23,476	-	3,100	525	41,392	-	-	72,729	6.6
42252875	HOWARD	-101.2600	32.1100	SAN ANDRES	1,337	811	10,919	-	1,276	384	22,859	-	-	37,587	7.9
42252876	HOWARD	-101.2600	32.1100	SAN ANDRES	2,120	680	23,086	-	2,591	793	38,964	-	-	68,233	7.5
42252877	HOWARD	-101.2600	32.1100	SAN ANDRES	2,745	883	23,156	-	2,483	788	40,864	-	-	70,920	7.5
42252883	HOWARD	-101.2600	32.1100	SAN ANDRES	4,276	1,854	33,015	-	2,776	793	61,420	-	-	104,135	6.6
42252885	HOWARD	-101.2600	32.1100	SAN ANDRES	3,105	1,329	30,201	-	3,063	898	53,064	-	-	91,659	6.7
42252886	HOWARD	-101.2600	32.1100	SAN ANDRES	3,131	1,390	29,613	-	2,229	691	53,176	-	-	90,231	6.6
42252887	HOWARD	-101.2600	32.1100	SAN ANDRES	2,470	1,126	19,491	-	2,147	964	35,647	-	-	61,845	7.5
42253818	HOWARD	-101.2600	32.1100	SAN ANDRES	3,466	2,778	24,613	-	3,407	619	57,324	-	-	92,207	6.3
42255599	HOWARD	-101.3400	32.0900	SAN ANDRES	2,490	1,114	24,273	-	2,932	717	42,557	-	-	74,084	7.0
42255601	HOWARD	-101.2600	32.1100	SAN ANDRES	2,650	1,103	28,943	-	234	693	51,950	-	-	85,574	7.0
42019280	HOWARD	-101.2400	32.2000	SAN ANGELO	2,664	2,093	72,720	-	4,760	24	120,196	-	-	203,316	6.9
42019281	HOWARD	-101.2400	32.2000	SAN ANGELO	3,624	1,474	30,597	-	3,092	108	56,078	-	-	95,562	7.8
42252867	HOWARD	-101.2400	32.2000	SAN ANGELO	4,706	2,159	38,954	-	2,750	121	72,589	-	-	121,279	7.3
42000272	HOWARD	-101.2600	32.2900	SANTA ROSA	534	230	5,983	-	3,819	155	7,981	-	-	18,807	-
42002355	HOWARD	-101.3300	32.0900	SEVEN RIVERS SAN ANDRES	2,818	994	29,407	-	2,002	798	51,340	-	-	87,377	-
42105597	HOWARD	-	-	SILURIAN - DEVONIAN	1,600	972	19,651	-	1,622	817	36,000	-	-	60,662	7.7
42003180	HOWARD	-101.3000	32.2300	WOLFCAMP	2,680	634	46,558	-	5,000	128	75,200	-	-	130,559	6.4
42003181	HOWARD	-101.3000	32.2300	WOLFCAMP	4,280	1,100	44,500	-	3,300	390	77,700	-	-	131,878	6.8
42002353	HOWARD	-101.3400	32.0900	YATES	868	292	4,969	-	3,856	154	7,118	-	-	17,256	-
42002354	HOWARD	-101.3400	32.0900	YATES	933	333	5,301	-	3,919	440	7,563	-	-	18,562	-
42002361	HOWARD	-101.3300	32.0900	YATES	1,907	1,036	16,622	-	3,766	1,392	28,461	-	-	53,192	-
42002624	HOWARD	-101.3600	32.0900	YATES	1,146	1,050	9,815	-	7,113	2,767	12,824	-	-	35,172	8.2
42002626	HOWARD	-101.3600	32.0900	YATES	1,251	1,023	9,817	-	7,358	925	14,369	-	-	34,744	7.7
42007223	HOWARD	-	-	YATES	2,100	1,116	21,103	-	4,950	491	37,668	-	-	67,819	6.6
42007312	HOWARD	-101.2600	32.1100	YATES	414	322	11,671	-	7,154	2,948	12,044	-	-	35,192	8.2
42105598	HOWARD	-101.2600	32.1100	YATES	1,624	690	-3	-	573	2,106	10,150	-	-	19,853	8.0
42252839	HOWARD	-101.2600	32.1100	YATES	2,101	906	17,376	-	3,912	859	29,654	-	-	54,913	8.6
42252889	HOWARD	-101.2600	32.1100	YATES	2,650	1,205	21,164	-	3,457	778	37,927	-	-	67,182	6.6

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42002359	HOWARD	-101.3300	32.0900	YATES GRAYBURG SAN ANDRES	2,687	983	27,825	-	2,200	887	48,434	-	-	83,035	-
**	IRION	-100.7060	31.4560	CANYON	11,350	1,610	54,790	534.0	10	196	105,300	430	-	-	6.3
**	IRION	-100.7140	31.2330	SAN ANGELO	831	599	15,840	206.0	20	198	26,360	360	-	-	7.4
**	IRION	-100.7520	31.2160	SAN ANGELO	1,290	701	27,100	216.0	10	294	42,790	60	-	-	6.3
**	IRION	-100.7160	31.1770	CANYON	12,740	1,830	61,420	431.0	11	72	123,600	480	-	-	6.3
**	IRION	-100.7600	31.1090	WOLFCAMP	50,960	2,780	47,460	2,560.0	350	94	176,320	320	-	-	6.5
42005030	MITCHELL	-101.0600	32.3600	-	4,528	3,525	78,988	-	2,288	262	138,290	-	-	227,881	-
42253613	MITCHELL	-100.6800	32.1000	-	12,466	2,448	60,745	-	8	159	123,530	-	-	199,613	5.4
42018274	MITCHELL	-100.6800	32.1000	CADDO	6,575	1,220	39,776	-	1,109	241	75,589	-	-	124,508	6.4
42000407	MITCHELL	-101.1300	32.4900	CLEAR FORK	3,563	1,570	36,107	-	1,014	492	65,971	-	-	109,161	-
42007241	MITCHELL	-101.1000	32.4000	CLEAR FORK	4,600	912	41,607	-	2,700	844	72,500	-	-	123,163	6.4
42105306	MITCHELL	-101.0700	32.4800	CLEAR FORK	5,840	4,106	-3	-	2,239	650	101,400	-	-	169,548	6.3
42105485	MITCHELL	-101.1000	32.4000	CLEAR FORK	5,529	1,758	-3	-	2,236	948	73,008	-	-	121,473	6.9
42105570	MITCHELL	-101.0700	32.3600	CLEAR FORK	4,185	2,145	-3	-	3,008	686	85,020	-	-	143,004	7.0
42105571	MITCHELL	-101.0700	32.3600	CLEAR FORK	4,296	2,003	-3	-	3,255	819	86,366	-	-	145,347	7.0
42105572	MITCHELL	-101.1000	32.4000	CLEAR FORK	3,933	1,792	-3	-	2,052	326	58,528	-	-	97,472	6.1
42105663	MITCHELL	-101.0700	32.3600	CLEAR FORK	4,204	2,129	-3	-	4,949	344	85,410	-	-	145,764	6.0
42253609	MITCHELL	-100.6800	32.1000	ELLENBURGER	2,146	442	19,904	-	1,907	622	33,972	-	-	58,994	7.5
42105569	MITCHELL	-101.0300	32.3100	ELLENBURGER	3,350	1,018	-3	-	3,717	722	41,880	-	-	74,140	7.0
42251507	MITCHELL	-100.7000	32.1200	ELLENBURGER	2,205	510	20,797	-	1,975	454	35,847	-	-	61,828	7.2
42251508	MITCHELL	-100.6600	32.1100	ELLENBURGER	3,364	875	30,560	-	1,853	339	54,624	-	-	91,955	5.8
42251509	MITCHELL	-100.6900	32.1100	ELLENBURGER	2,163	510	20,900	-	1,996	539	35,844	-	-	61,997	7.1
42251510	MITCHELL	-100.6900	32.1200	ELLENBURGER	2,236	340	21,632	-	1,996	683	36,470	-	-	63,398	6.9
42251511	MITCHELL	-100.6800	32.1200	ELLENBURGER	2,414	778	23,203	-	1,911	195	40,841	-	-	69,388	5.3
42251953	MITCHELL	-100.6900	32.1200	ELLENBURGER	2,711	456	25,226	-	2,249	508	42,990	-	-	74,150	6.5
42251954	MITCHELL	-100.6900	32.1200	ELLENBURGER	2,016	632	21,314	-	1,766	644	36,568	-	-	62,941	6.5
42251956	MITCHELL	-100.6900	32.1200	ELLENBURGER	2,905	790	25,896	-	2,242	188	45,687	-	-	77,716	6.4
42105308	MITCHELL	-101.1200	32.3800	GLORIETA	3,672	3,963	-3	-	2,236	172	68,688	-	-	112,710	6.9
42253617	MITCHELL	-100.6800	32.1000	MISSISSIPPI CHAT	2,728	608	21,533	-	2,017	708	37,944	-	-	65,582	6.9
42253618	MITCHELL	-100.6800	32.1000	MISSISSIPPI CHAT	2,326	778	16,272	-		488	29,833	-	-	-3	7.2
42003560	MITCHELL	-100.7100	32.3000	MISSISSIPPIAN	970	437	17,152	-	2,184	895	27,360	-	-	48,998	7.2
42000406	MITCHELL	-101.1300	32.5200	PENNSYLVANIAN	3,430	729	35,534	-	1,501	118	61,956	-	-	103,468	6.7
42007239	MITCHELL	-101.0700	32.3600	PENNSYLVANI PERMIAN	4,934	4,927	89,633	-	2,865	127	159,172	-	-	261,657	-
42007240	MITCHELL	-101.0700	32.3600	PERMIAN	4,719	3,347	53,169	-	3,222	255	97,601	-	-	162,314	-
42105307	MITCHELL	-101.1100	32.3500	SAN ANDRES	4,586	3,556	44,622	-	-3	159	87,360	-	-	140,283	6.6
42105832	MITCHELL	-	-	SAN ANDRES	5,918	3,918	39,897	-	3,041	361	80,983	-	-	134,146	7.7
42007588	MITCHELL	-101.0700	32.3600	SANTA ROSA	346	97	3,766	-	708	371	5,980	-	-	11,287	7.7
42007589	MITCHELL	-101.0700	32.3600	SANTA ROSA	346	128	4,274	-	775	329	6,835	-	-	12,711	7.6
42253614	MITCHELL	-101.0700	32.3600	SANTA ROSA	182	65	2,791	-	700	419	4,074	-	-	8,252	8.0
42000146	MITCHELL	-100.6700	32.1200	STRAWN	12,435	2,023	59,120	-	47	64	119,019	-	-	192,709	6.3
42000409	MITCHELL	-101.0900	32.5100	STRAWN	13,704	3,109	74,802	-	18	247	148,605	-	-	240,610	6.3
42005029	MITCHELL	-100.6700	32.1000	STRAWN	7,615	778	42,881	-	954	143	80,915	-	-	133,889	5.4
42018275	MITCHELL	-100.6800	32.1000	STRAWN	11,699	1,835	55,636	-	75	98	111,761	-	-	181,104	6.7
42251486	MITCHELL	-100.6900	32.1200	STRAWN	11,463	2,020	64,695	-	26	188	125,985	-	-	204,577	5.8
42251487	MITCHELL	-100.7000	32.1100	STRAWN	10,896	2,086	63,498	-	88	481	122,461	-	-	199,685	5.8
42251488	MITCHELL	-100.6900	32.1100	STRAWN	10,652	1,784	58,529	-	25	63	114,372	-	-	185,677	5.4
42251489	MITCHELL	-100.6900	32.1100	STRAWN	11,465	2,055	65,047	-	52	137	127,142	-	-	206,301	5.1
42251490	MITCHELL	-100.7000	32.1200	STRAWN	11,302	2,653	62,807	-	46	239	124,707	-	-	202,355	5.4
42251491	MITCHELL	-100.7000	32.1200	STRAWN	12,499	2,534	61,360	-	14	81	124,993	-	-	202,283	5.4

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42251492	MITCHELL	-100.7000	32.1200	STRAWN	7,621	1,267	41,165	-	382	539	80,145	-	-	131,166	5.5
42251493	MITCHELL	-100.6900	32.1000	STRAWN	9,769	2,271	59,310	-	34	313	115,363	-	-	187,236	5.9
42251494	MITCHELL	-100.7000	32.1100	STRAWN	12,500	2,546	59,206	-	18	1,227	120,458	-	-	196,285	5.2
42251495	MITCHELL	-100.7000	32.1100	STRAWN	12,856	2,378	62,801	-	9	947	126,285	-	-	205,481	5.0
42251497	MITCHELL	-100.7000	32.1000	STRAWN	3,422	713	18,049	-	620	264	35,264	-	-	58,338	7.5
42251500	MITCHELL	-100.6800	32.1100	STRAWN	4,086	807	24,753	-	438	166	47,398	-	-	77,659	6.3
42251503	MITCHELL	-100.6800	32.1100	STRAWN	3,119	492	19,094	-	560	249	35,789	-	-	59,307	6.9
42251505	MITCHELL	-100.6900	32.1000	STRAWN	12,961	2,240	61,512	-	39	605	123,933	-	-	201,450	5.3
42251506	MITCHELL	-100.6900	32.1000	STRAWN	12,743	2,435	61,100	-	6	146	124,020	-	-	200,670	5.9
42251517	MITCHELL	-100.7100	32.1100	STRAWN	12,279	2,501	60,943	-	35	332	122,796	-	-	199,096	5.0
42251518	MITCHELL	-100.7100	32.1100	STRAWN	13,550	4,478	58,041	-	2	84	126,470	-	-	202,778	5.4
42251519	MITCHELL	-100.6800	32.1100	STRAWN	13,021	3,061	66,704	-	8	142	134,780	-	-	218,054	5.5
42251520	MITCHELL	-100.6900	32.1000	STRAWN	12,602	1,749	59,949	-	24	95	120,352	-	-	195,055	5.5
42251955	MITCHELL	-100.7000	32.1200	STRAWN	12,274	2,478	61,030	-	47	193	122,742	-	-	199,018	5.3
42253605	MITCHELL	-100.6800	32.1000	STRAWN	6,072	403	29,091	-	373	134	56,376	-	-	92,456	6.1
42253606	MITCHELL	-100.6800	32.1000	STRAWN	14,034	2,042	71,541	-	19	151	141,484	-	-	229,571	5.6
42253608	MITCHELL	-100.6800	32.1000	STRAWN	12,733	1,751	62,530	-	11	211	123,922	-	-	201,430	5.9
42253611	MITCHELL	-100.6800	32.1000	STRAWN	5,246	543	29,156	-	260	203	55,652	-	-	91,121	6.6
42253612	MITCHELL	-100.6800	32.1000	STRAWN	14,778	1,819	60,591	-	14	210	125,048	-	-	202,748	5.8
42253620	MITCHELL	-100.7400	32.1300	STRAWN	13,036	1,904	60,194	-	0	87	122,429	-	-	198,178	5.3
42255745	MITCHELL	-100.6700	32.0900	STRAWN	3,997	967	24,682	-	293	235	47,571	-	-	77,755	6.4
42000414	MITCHELL	-101.0900	32.2900	WICHITA ALBANY	3,310	1,140	29,720	-	3,670	366	52,500	-	-	91,262	7.6
42001468	NOLAN	-100.5200	32.4100	-	616	198	8,216	-	5,255	1,013	9,870	-	-	25,167	7.2
42002066	NOLAN	-100.1900	32.1300	-	4,541	1,436	35,197	-	1,957	463	64,741	-	-	108,334	7.0
42002067	NOLAN	-100.1900	32.1300	-	6,302	1,352	29,836	-	1,189	143	60,102	-	-	98,923	6.1
42007131	NOLAN	-	-	-	3,944	0	21,458	-	924	60	39,402	-	-	66,459	7.1
42252816	NOLAN	-100.6000	32.1900	-	3,009	729	27,667	-	2,123	183	48,470	-	-	82,181	7.1
42252836	NOLAN	-100.6100	32.0800	-	1,236	273	10,521	-	317	256	18,796	-	-	31,399	6.2
42000168	NOLAN	-100.5700	32.2000	CADDO	5,882	1,311	38,083	-	606	206	72,385	-	-	118,474	6.3
42000470	NOLAN	-100.1700	32.4800	CADDO	3,181	718	27,582	-	1,750	256	49,400	-	-	83,580	7.9
42000471	NOLAN	-100.1700	32.4800	CADDO	2,280	632	22,798	-	2,125	195	39,900	-	-	68,491	7.3
42000474	NOLAN	-100.3900	32.5000	CADDO	8,600	1,672	29,428	-	1,298	328	64,798	-	-	106,638	6.0
42001825	NOLAN	-100.5700	32.1900	CADDO	5,672	1,071	37,704	-	697	54	70,753	-	-	115,950	7.2
42256542	NOLAN	-100.5600	32.1400	CADDO	4,554	4,252	115,749	-	108	7	198,909	-	-	323,581	6.2
42001753	NOLAN	-100.2000	32.4100	CAMBRIAN	1,870	376	21,843	-	1,869	888	36,240	-	-	63,089	6.7
42001754	NOLAN	-100.5500	32.3300	CAMBRIAN	2,000	352	18,130	-	1,897	828	30,690	-	-	53,897	7.4
42000177	NOLAN	-100.4300	32.2900	CANYON	12,661	2,032	43,364	-	134	0	95,113	-	-	153,303	5.6
42000185	NOLAN	-100.5100	32.3000	CANYON	10,609	1,675	37,013	-	956	155	79,928	-	-	130,336	6.2
42000232	NOLAN	-100.5000	32.5100	CANYON	11,212	1,587	43,452	-	94	90	91,348	-	-	147,782	6.4
42000233	NOLAN	-100.5000	32.5100	CANYON	16,590	2,360	59,864	-	99	21	128,456	-	-	207,390	6.2
42001820	NOLAN	-100.5700	32.1900	CANYON	15,283	2,534	53,790	-	138	49	117,245	-	-	189,039	5.9
42001824	NOLAN	-100.5700	32.2000	CANYON	12,485	2,308	53,949	-	192	197	111,755	-	-	180,886	6.1
42007129	NOLAN	-100.4400	32.3500	CANYON	6,256	972	27,258	-	0	16	55,978	-	-	90,857	-
42018469	NOLAN	-100.6200	32.1800	CANYON	8,044	1,486	39,669	-	648	248	79,112	-	-	129,208	6.2
42252787	NOLAN	-100.6000	32.1900	CANYON	16,411	1,987	44,768	-	297	185	105,053	-	-	169,874	5.4
42252788	NOLAN	-100.6000	32.1900	CANYON	13,961	2,144	49,255	-	232	261	106,999	-	-	173,247	5.6
42252790	NOLAN	-100.6000	32.1900	CANYON	12,217	2,032	50,078	-	175	48	104,603	-	-	169,156	6.0
42252792	NOLAN	-100.6000	32.1900	CANYON	12,154	2,246	54,372	-	163	30	111,758	-	-	180,724	5.6
42105493	NOLAN	-100.4400	32.3500	CANYON SAND	13,376	3,314	50,492	-	705	276	111,320	-	-	179,483	5.9
42009358	NOLAN	-	-	CISCO	4,492	1,522	39,381	-	1,944	495	71,417	-	-	119,274	6.5

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42009356	NOLAN	-	-	COLEMAN JUNCTION	2,713	1,030	28,186	-	4,452	453	48,108	-	-	85,394	7.3
42252793	NOLAN	-	-	ELLENBERGER	13,783	4,135	41,352	-	460	723	99,266	-	-	159,719	5.5
42000180	NOLAN	-100.5100	32.3000	ELLENBURGER	1,762	471	21,524	-	1,649	1,016	35,885	-	-	62,307	6.8
42000468	NOLAN	-100.3900	32.4400	ELLENBURGER	10,492	1,062	40,925	-	233	96	85,259	-	-	138,850	7.3
42001368	NOLAN	-100.5400	32.1800	ELLENBURGER	2,077	530	22,837	-	2,095	513	38,594	-	-	66,646	6.9
42002756	NOLAN	-100.5200	32.2800	ELLENBURGER	1,842	464	20,365	-	1,951	609	34,224	-	-	59,455	7.1
42105309	NOLAN	-100.2800	32.1400	ELLENBURGER	2,215	1,750	-3	-	2,137	643	36,784	-	-	64,638	7.3
42105491	NOLAN	-	-	ELLENBURGER	3,182	1,400	-3	-	1,026	515	43,974	-	-	72,998	6.4
42105494	NOLAN	-100.3000	32.1300	ELLENBURGER	3,693	1,773	-3	-	2,212	707	38,760	-	-	66,049	6.5
42105573	NOLAN	-100.1800	32.4800	ELLENBURGER	1,517	946	-3	-	2,101	782	29,110	-	-	50,446	7.0
42256571	NOLAN	-100.5400	32.1800	ELLENBURGER	3,283	680	14,810	-	1,069	125	29,765	-	-	49,732	7.4
42000469	NOLAN	-100.2700	32.1000	GARDNER	1,662	379	17,536	-	2,231	410	29,656	-	-	52,230	7.4
42105661	NOLAN	-100.3000	32.1300	HICKORY SAND	2,537	1,113	-3	-	1,910	926	36,608	-	-	62,958	6.3
42007132	NOLAN	-100.1900	32.4100	HONEYCUTT	2,661	330	22,652	-	1,145	199	39,684	-	-	67,654	7.3
42256552	NOLAN	-100.6100	32.1800	NOODLE CREEK	2,795	754	24,698	-	3,269	585	42,671	-	-	74,893	6.5
42256553	NOLAN	-100.6100	32.1800	NOODLE CREEK	11,727	2,244	56,042	-	76	51	116,143	-	-	188,252	5.2
42002911	NOLAN	-100.5300	32.4700	PENNSYLVANIAN	6,529	1,097	25,919	-	226	156	54,457	-	-	88,384	6.7
42002927	NOLAN	-100.5300	32.4600	PENNSYLVANIAN	6,345	990	25,702	-	230	158	53,485	-	-	86,910	6.4
42002928	NOLAN	-100.5300	32.4600	PENNSYLVANIAN	6,345	969	24,891	-	230	141	52,182	-	-	84,757	6.0
42000183	NOLAN	-100.5100	32.3000	PENNSYLVANIAN REEF	11,393	2,150	43,390	-	1,119	147	93,393	-	-	152,145	6.5
42000184	NOLAN	-100.5100	32.3000	PENNSYLVANIAN REEF	16,355	2,738	55,613	-	558	78	122,107	-	-	197,393	6.3
42000187	NOLAN	-100.5100	32.4800	PENNSYLVANIAN REEF	7,884	1,304	27,329	-	984	91	59,132	-	-	96,725	6.8
42001466	NOLAN	-100.5200	32.4100	PENNSYLVANIAN REEF	6,565	862	22,255	-	258	82	48,199	-	-	78,220	6.2
42001467	NOLAN	-100.5200	32.4100	PENNSYLVANIAN REEF	6,575	1,121	23,166	-	341	67	50,334	-	-	81,603	6.0
42002755	NOLAN	-100.4700	32.2800	PENNSYLVANIAN REEF	13,994	2,666	49,126	-	285	60	110,142	-	-	178,804	6.3
42002884	NOLAN	-100.5300	32.4800	PENNSYLVANIAN REEF	9,771	1,619	37,969	-	232	56	80,350	-	-	129,999	6.0
42002885	NOLAN	-100.5300	32.4800	PENNSYLVANIAN REEF	9,589	1,683	37,585	-	243	71	79,608	-	-	128,778	6.2
42002886	NOLAN	-100.5300	32.4800	PENNSYLVANIAN REEF	9,473	1,588	36,532	-	246	84	77,486	-	-	125,408	6.3
42002888	NOLAN	-100.5100	32.1200	PENNSYLVANIAN REEF	17,047	2,780	50,173	-	161	48	117,385	-	-	189,831	6.6
42002901	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	7,611	1,216	28,852	-	246	119	61,246	-	-	99,289	6.1
42002904	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	11,481	1,948	43,253	-	207	67	92,489	-	-	149,445	5.9
42002905	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	14,667	2,174	53,172	-	162	42	114,131	-	-	184,349	6.0
42002906	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	15,332	2,410	55,383	-	160	35	119,415	-	-	192,735	6.0
42002908	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	10,043	1,714	37,301	-	196	134	80,059	-	-	129,449	6.4

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42002909	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	11,154	1,916	40,619	-	191	67	87,773	-	-	141,719	5.9
42002913	NOLAN	-100.5300	32.4700	PENNSYLVANIAN REEF	15,703	2,775	55,387	-	159	90	121,101	-	-	195,216	6.3
42002914	NOLAN	-100.5200	32.4600	PENNSYLVANIAN REEF	4,966	867	18,214	-	178	113	39,201	-	-	63,538	6.2
42002915	NOLAN	-100.5200	32.4600	PENNSYLVANIAN REEF	4,345	845	18,809	-	192	117	39,779	-	-	64,557	6.4
42002919	NOLAN	-100.5200	32.4600	PENNSYLVANIAN REEF	3,085	503	12,396	-	176	81	25,861	-	-	42,102	6.8
42002923	NOLAN	-100.5200	32.4600	PENNSYLVANIAN REEF	4,328	753	17,222	-	173	166	36,182	-	-	58,824	6.9
42002926	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	6,523	1,083	24,821	-	215	176	52,707	-	-	85,526	6.3
42002929	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	6,602	1,022	26,096	-	230	118	54,658	-	-	88,726	6.0
42002930	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	7,152	1,184	27,754	-	245	129	58,640	-	-	95,102	6.1
42002931	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	15,405	2,690	57,322	-	159	11	123,359	-	-	198,946	5.6
42002932	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	19,327	2,475	46,858	-	176	86	113,490	-	-	182,412	5.8
42002933	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	12,837	2,066	48,432	-	485	82	103,231	-	-	166,838	6.0
42002936	NOLAN	-100.5300	32.4600	PENNSYLVANIAN REEF	8,436	1,550	33,469	-	225	124	70,810	-	-	114,615	6.7
42002974	NOLAN	-100.5200	32.4600	PENNSYLVANIAN REEF	14,859	2,750	54,286	-	189	35	117,848	-	-	189,968	5.7
42251785	NOLAN	-100.6600	32.1500	SNRF	2,325	581	20,725	-	1,933	695	35,935	-	-	62,195	6.9
42251786	NOLAN	-100.6600	32.1500	SNRF	2,268	686	27,610	-	1,944	394	46,920	-	-	79,823	7.0
42000182	NOLAN	-100.5100	32.3000	STRAWN	11,905	1,507	43,110	-	733	39	92,971	-	-	150,812	6.7
42000186	NOLAN	-100.4700	32.4700	STRAWN	18,627	1,332	26,078	-	811	37	76,448	-	-	123,334	6.9
42000190	NOLAN	-100.5000	32.3600	STRAWN	15,164	1,948	55,632	-	163	0	118,204	-	-	191,111	5.3
42000472	NOLAN	-100.1700	32.4800	STRAWN	19,368	1,998	62,416	-	67	27	136,863	-	-	221,437	5.6
42001774	NOLAN	-100.6400	32.1400	STRAWN	7,427	1,614	45,988	-	300	42	88,512	-	-	143,884	6.2
42001775	NOLAN	-100.6400	32.1400	STRAWN	7,037	1,361	46,182	-	306	127	87,326	-	-	142,339	6.1
42001777	NOLAN	-100.6300	32.1400	STRAWN	8,486	1,473	44,171	-	99	-3	87,273	-	-	141,501	7.3
42001778	NOLAN	-100.6300	32.1500	STRAWN	2,145	840	19,837	-	3,975	251	33,757	-	-	60,807	8.2
42001780	NOLAN	-100.6300	32.1500	STRAWN	6,221	1,036	30,620	-	229	136	60,988	-	-	99,228	6.2
42001781	NOLAN	-100.6300	32.1500	STRAWN	6,341	1,298	36,895	-	196	179	71,644	-	-	116,553	6.6
42001784	NOLAN	-100.6300	32.1600	STRAWN	4,977	965	32,682	-	244	242	61,693	-	-	100,804	6.7
42001785	NOLAN	-100.6300	32.1600	STRAWN	6,486	1,089	39,997	-	265	174	76,023	-	-	124,035	6.6
42001787	NOLAN	-100.6300	32.1700	STRAWN	6,223	1,262	40,194	-	255	195	76,362	-	-	124,491	6.1
42001788	NOLAN	-100.6200	32.1600	STRAWN	9,446	1,781	51,162	-	184	137	100,576	-	-	163,286	6.2
42001790	NOLAN	-100.6000	32.1700	STRAWN	2,570	1,189	25,882	-	1,761	267	46,468	-	-	78,137	6.8
42001792	NOLAN	-100.6100	32.1800	STRAWN	5,955	570	27,199	-	178	279	53,843	-	-	88,024	6.8
42001794	NOLAN	-100.6000	32.1700	STRAWN	4,656	955	26,187	-	177	207	51,152	-	-	83,333	7.1
42001795	NOLAN	-100.5800	32.1800	STRAWN	12,700	2,233	54,190	-	139	94	112,377	-	-	181,733	6.0
42001796	NOLAN	-100.6100	32.1700	STRAWN	1,876	569	10,547	-	275	436	20,788	-	-	34,490	7.3
42001797	NOLAN	-100.6100	32.1700	STRAWN	3,765	721	26,669	-	748	424	49,088	-	-	81,415	6.5
42001798	NOLAN	-100.6200	32.1700	STRAWN	9,959	1,820	47,844	-	586	179	96,160	-	-	156,547	6.2

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42001799	NOLAN	-100.6200	32.1700	STRAWN	9,423	1,820	50,435	-	180	128	99,540	-	-	161,526	5.9
42001800	NOLAN	-100.6100	32.1600	STRAWN	4,677	1,067	57,966	-	158	124	100,573	-	-	164,565	6.4
42001801	NOLAN	-100.6200	32.1600	STRAWN	3,647	649	45,172	-	168	187	77,760	-	-	127,582	6.6
42001802	NOLAN	-100.6200	32.1600	STRAWN	7,221	1,585	36,257	-	181	193	73,053	-	-	118,490	6.4
42001803	NOLAN	-100.6200	32.1600	STRAWN	9,384	1,485	44,836	-	304	176	89,737	-	-	145,921	6.3
42001804	NOLAN	-100.6200	32.1600	STRAWN	3,210	698	42,308	-	186	207	72,688	-	-	119,297	6.5
42001806	NOLAN	-100.6000	32.1800	STRAWN	2,752	617	13,497	-	168	411	27,119	-	-	44,564	6.7
42001807	NOLAN	-100.6000	32.1800	STRAWN	3,371	601	15,120	-	223	302	30,690	-	-	50,307	7.0
42001808	NOLAN	-100.6000	32.1800	STRAWN	820	155	4,239	-	126	394	8,119	-	-	13,852	7.4
42001809	NOLAN	-100.6100	32.1700	STRAWN	4,773	904	28,544	-	224	85	54,879	-	-	89,408	6.9
42001810	NOLAN	-100.6200	32.1700	STRAWN	2,308	417	13,368	-	50	185	25,769	-	-	42,098	6.9
42001811	NOLAN	-100.6200	32.1700	STRAWN	4,340	925	22,937	-	178	267	45,460	-	-	74,107	6.5
42001812	NOLAN	-100.6200	32.1700	STRAWN	3,365	737	18,490	-	146	249	36,358	-	-	59,345	6.8
42001813	NOLAN	-100.6300	32.1700	STRAWN	8,362	1,335	41,990	-	337	83	83,133	-	-	135,240	5.6
42001814	NOLAN	-100.6300	32.1700	STRAWN	9,243	1,549	42,347	-	303	23	85,923	-	-	139,387	5.4
42001815	NOLAN	-100.5700	32.2000	STRAWN	12,828	2,580	54,914	-	128	18	114,783	-	-	185,252	6.0
42001816	NOLAN	-100.5700	32.1900	STRAWN	7,116	1,334	32,202	-	97	41	66,035	-	-	106,825	5.7
42001821	NOLAN	-100.5700	32.1900	STRAWN	12,152	2,284	49,074	-	266	90	103,582	-	-	167,447	6.0
42001822	NOLAN	-100.5700	32.1800	STRAWN	36,605	2,611	36,765	-	247	48	128,866	-	-	205,143	5.7
42002169	NOLAN	-100.6200	32.2100	STRAWN	4,057	764	41,722	-	701	331	73,048	-	-	120,623	6.3
42002890	NOLAN	-100.6000	32.1800	STRAWN	868	160	4,059	-	220	349	7,899	-	-	13,555	7.3
42002891	NOLAN	-100.6100	32.1800	STRAWN	10,187	1,875	49,536	-	140	61	99,735	-	-	161,535	6.8
42002892	NOLAN	-100.6400	32.1800	STRAWN	3,846	810	36,962	-	1,165	170	65,200	-	-	108,152	6.7
42002893	NOLAN	-100.6100	32.1800	STRAWN	9,102	1,758	47,613	-	143	24	94,524	-	-	153,163	5.7
42002894	NOLAN	-100.6400	32.1700	STRAWN	2,902	665	29,791	-	1,538	291	51,704	-	-	86,891	7.0
42002895	NOLAN	-100.6400	32.1700	STRAWN	2,855	878	30,283	-	1,524	364	52,968	-	-	88,872	7.2
42002899	NOLAN	-100.6100	32.1800	STRAWN	11,138	1,585	50,524	-	128	158	102,047	-	-	165,580	6.7
42002937	NOLAN	-100.6400	32.1800	STRAWN	3,725	736	37,314	-	1,252	115	65,281	-	-	108,423	7.1
42002940	NOLAN	-100.6200	32.1900	STRAWN	7,754	1,441	44,601	-	308	52	86,436	-	-	140,594	5.9
42002941	NOLAN	-100.6100	32.1900	STRAWN	6,272	1,232	34,140	-	193	48	67,159	-	-	109,044	5.3
42002942	NOLAN	-100.6300	32.1700	STRAWN	7,215	1,283	45,835	-	697	158	86,901	-	-	141,645	6.0
42002943	NOLAN	-100.6200	32.1900	STRAWN	9,199	1,598	49,294	-	253	95	96,699	-	-	157,137	6.1
42002945	NOLAN	-100.6400	32.1500	STRAWN	7,064	653	18,270	-	396	145	42,195	-	-	68,724	6.0
42002946	NOLAN	-100.6500	32.1500	STRAWN	5,939	1,225	41,757	-	337	176	78,111	-	-	127,545	7.0
42002947	NOLAN	-100.6500	32.1500	STRAWN	4,340	994	36,991	-	856	218	66,853	-	-	110,252	6.8
42002948	NOLAN	-100.6500	32.1500	STRAWN	4,364	868	36,411	-	937	397	65,472	-	-	108,449	6.7
42002950	NOLAN	-100.5800	32.1800	STRAWN	2,017	427	10,336	-	157	327	20,447	-	-	33,713	7.3
42002951	NOLAN	-100.6200	32.1500	STRAWN	132	40	894	-	92	259	1,510	-	-	2,927	7.1
42002953	NOLAN	-100.5900	32.1800	STRAWN	1,427	208	5,833	-	263	1,697	10,942	-	-	20,370	7.8
42002955	NOLAN	-100.5800	32.1800	STRAWN	3,121	1,479	13,576	-	177	278	30,477	-	-	49,110	6.7
42002956	NOLAN	-100.5800	32.1800	STRAWN	11,814	1,257	52,213	-	72	49	104,991	-	-	170,396	6.0
42002959	NOLAN	-100.6100	32.1600	STRAWN	7,996	1,595	46,190	-	167	140	89,814	-	-	145,902	6.1
42002960	NOLAN	-100.6200	32.1600	STRAWN	7,349	821	12,727	-	220	242	34,718	-	-	56,077	6.9
42002961	NOLAN	-100.6200	32.1600	STRAWN	3,663	542	19,248	-	187	252	37,455	-	-	61,348	6.8
42002963	NOLAN	-100.6200	32.1600	STRAWN	9,342	1,510	41,483	-	223	101	84,672	-	-	137,330	6.5
42002966	NOLAN	-100.6300	32.1500	STRAWN	8,567	1,757	46,523	-	177	109	91,819	-	-	148,952	6.3
42002967	NOLAN	-100.6400	32.1400	STRAWN	7,997	1,387	42,697	-	259	61	83,801	-	-	136,201	5.9
42002968	NOLAN	-100.6400	32.1500	STRAWN	4,830	825	33,849	-	270	86	62,889	-	-	102,748	6.8
42002973	NOLAN	-100.5700	32.2100	STRAWN	415	115	2,686	-	983	154	4,143	-	-	8,525	7.9
42002976	NOLAN	-100.6300	32.1700	STRAWN	7,615	1,517	40,681	-	248	0	80,439	-	-	130,500	5.3
42002978	NOLAN	-100.6100	32.1700	STRAWN	5,787	1,756	31,964	-	122	217	64,428	-	-	104,275	6.7

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42002979	NOLAN	-100.6000	32.1800	STRAWN	9,900	1,918	46,177	-	155	108	94,132	-	-	152,390	6.6
42002980	NOLAN	-100.6400	32.1700	STRAWN	8,505	1,244	40,178	-	-3	-3	80,626	-	-	130,554	-
42002981	NOLAN	-100.6000	32.1700	STRAWN	7,187	1,445	36,394	-	162	182	72,820	-	-	118,190	6.7
42002982	NOLAN	-100.6000	32.1700	STRAWN	12,298	2,011	49,996	-	159	72	104,552	-	-	169,088	6.3
42002992	NOLAN	-100.6600	32.1500	STRAWN	2,334	985	29,803	-	3,440	170	50,318	-	-	87,050	6.6
42002994	NOLAN	-100.6500	32.1400	STRAWN	7,120	1,136	43,064	-	275	21	79,115	-	-	130,731	5.4
42003001	NOLAN	-100.6300	32.1400	STRAWN	1,827	332	9,174	-	186	400	17,978	-	-	29,896	7.6
42003003	NOLAN	-100.6200	32.1400	STRAWN	2,232	419	11,460	-	177	48	22,683	-	-	37,019	5.3
42007133	NOLAN	-100.1900	32.4100	STRAWN	5,836	291	27,401	-	742	65	52,912	-	-	88,330	5.9
42007134	NOLAN	-100.4400	32.3500	STRAWN	18,446	1,070	62,856	-	955	27	132,150	-	-	216,705	5.5
42007416	NOLAN	-100.6200	32.1800	STRAWN	11,137	2,204	52,198	-	27	-3	106,593	-	-	172,159	7.0
42007420	NOLAN	-100.6200	32.1800	STRAWN	9,939	1,988	48,877	-	144	194	98,524	-	-	159,667	6.6
42007678	NOLAN	-100.6200	32.1800	STRAWN	2,703	1,328	34,518	-	4,402	484	58,346	-	-	101,781	7.2
42007691	NOLAN	-	-	STRAWN	2,255	562	26,279	-	1,958	582	44,366	-	-	76,001	6.8
42018400	NOLAN	-	-	STRAWN	14,347	2,193	48,903	-	2,005	97	105,621	-	-	173,165	6.3
42105310	NOLAN	-100.4700	32.4500	STRAWN	20,837	2,529	-3	-	522	99	134,244	-	-	216,709	6.4
42105497	NOLAN	-	-	STRAWN	11,827	2,341	-3	-	414	242	117,824	-	-	190,888	5.6
42105575	NOLAN	-	-	STRAWN	14,175	2,324	-3	-	0	189	126,000	-	-	202,875	5.5
42105664	NOLAN	-100.4300	32.3700	STRAWN	1,821	652	12,769	-	-3	543	24,840	-	-	40,626	6.3
42251715	NOLAN	-100.5700	32.2000	STRAWN	12,837	2,582	54,953	-	128	18	114,865	-	-	185,384	6.0
42251716	NOLAN	-100.5700	32.2000	STRAWN	2,087	519	10,500	-	204	296	21,000	-	-	34,607	6.8
42251718	NOLAN	-100.5700	32.2000	STRAWN	2,018	419	10,452	-	244	154	20,801	-	-	34,110	7.0
42251721	NOLAN	-100.5800	32.1800	STRAWN	1,598	462	10,350	-	842	400	19,164	-	-	32,825	7.2
42251728	NOLAN	-100.6200	32.1700	STRAWN	3,851	790	21,303	-	167	330	41,556	-	-	68,013	6.4
42251729	NOLAN	-100.6200	32.1700	STRAWN	3,681	2,845	38,553	-	-3	207	74,282	-	-	119,648	6.9
42251734	NOLAN	-100.5700	32.2000	STRAWN	1,304	214	1,812	-	44	146	5,607	-	-	9,126	6.4
42251738	NOLAN	-100.6400	32.1800	STRAWN	8,657	1,191	44,771	-	424	70	87,467	-	-	142,581	5.9
42251746	NOLAN	-100.5800	32.1800	STRAWN	2,398	324	12,852	-	189	230	24,732	-	-	40,725	7.5
42251749	NOLAN	-100.6200	32.1700	STRAWN	9,629	1,930	51,022	-	144	97	101,171	-	-	163,994	6.5
42251751	NOLAN	-100.6200	32.1700	STRAWN	794	214	2,242	-	475	478	4,878	-	-	9,096	7.3
42251759	NOLAN	-100.6200	32.1600	STRAWN	9,343	2,176	52,286	-	138	72	103,353	-	-	167,369	6.2
42251761	NOLAN	-100.6200	32.1600	STRAWN	2,940	697	21,741	-	905	310	39,911	-	-	66,561	6.7
42251763	NOLAN	-100.6200	32.1600	STRAWN	5,384	1,077	32,449	-	196	108	62,491	-	-	101,705	5.6
42251765	NOLAN	-100.6200	32.1500	STRAWN	921	190	3,661	-	3,450	162	5,188	-	-	13,570	7.4
42251766	NOLAN	-100.6300	32.1500	STRAWN	2,185	518	13,502	-	162	334	25,871	-	-	42,576	7.2
42251772	NOLAN	-100.6300	32.1400	STRAWN	2,347	571	16,027	-	444	271	30,089	-	-	49,764	7.0
42251773	NOLAN	-100.6300	32.1400	STRAWN	2,326	588	11,994	-	104	287	24,092	-	-	39,410	7.2
42251776	NOLAN	-100.6300	32.1500	STRAWN	7,765	1,592	42,163	-	160	99	83,215	-	-	134,994	6.3
42251787	NOLAN	-100.5700	32.2000	STRAWN	2,927	559	15,674	-	172	312	30,725	-	-	50,385	6.9
42251788	NOLAN	-100.5700	32.2000	STRAWN	1,054	260	4,969	-	449	295	9,786	-	-	16,829	6.4
42252786	NOLAN	-100.6000	32.1900	STRAWN	11,553	2,044	53,003	-	113	59	108,004	-	-	174,776	6.5
42252798	NOLAN	-100.6000	32.1900	STRAWN	2,268	833	25,974	-	1,303	227	45,402	-	-	76,007	6.8
42252799	NOLAN	-100.6000	32.1900	STRAWN	11,640	2,010	55,686	-	150	9	112,199	-	-	181,694	6.1
42252801	NOLAN	-100.6000	32.1900	STRAWN	5,917	1,060	39,053	-	305	222	73,346	-	-	119,903	6.6
42252804	NOLAN	-100.6000	32.1900	STRAWN	3,037	794	28,980	-	400	169	51,977	-	-	85,357	6.7
42252805	NOLAN	-100.6000	32.1900	STRAWN	3,275	1,017	32,019	-	1,173	291	57,089	-	-	94,864	7.3
42252806	NOLAN	-100.6000	32.1900	STRAWN	4,160	403	28,063	-	135	208	51,850	-	-	85,121	8.5
42252807	NOLAN	-100.6000	32.1900	STRAWN	9,444	2,098	49,896	-	343	100	99,447	-	-	161,329	6.7
42252809	NOLAN	-100.6000	32.1900	STRAWN	2,617	1,067	28,561	-	4,171	381	48,659	-	-	85,455	6.6
42252810	NOLAN	-100.6000	32.1900	STRAWN	3,563	624	21,229	-	235	218	40,556	-	-	66,426	7.4
42252811	NOLAN	-100.6000	32.1900	STRAWN	7,017	1,511	44,400	-	120	101	85,128	-	-	138,278	7.0

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42252812	NOLAN	-100.6000	32.1900	STRAWN	6,997	1,399	44,133	-	236	164	84,237	-	-	137,166	6.8
42252813	NOLAN	-100.6000	32.1900	STRAWN	6,732	1,485	43,668	-	158	158	83,365	-	-	135,567	6.6
42252814	NOLAN	-100.6000	32.1900	STRAWN	6,053	1,109	38,210	-	246	254	72,530	-	-	118,402	6.6
42252817	NOLAN	-100.6000	32.1900	STRAWN	2,347	570	11,102	-	35	53	22,875	-	-	36,982	5.8
42252818	NOLAN	-100.6000	32.1900	STRAWN	4,774	973	29,232	-	188	56	56,185	-	-	91,408	6.5
42252819	NOLAN	-100.6000	32.1900	STRAWN	11,100	1,951	51,161	-	186	11	104,065	-	-	168,474	5.1
42252821	NOLAN	-100.6000	32.1900	STRAWN	11,016	2,229	52,874	-	119	115	107,360	-	-	173,714	6.2
42252822	NOLAN	-100.6000	32.1900	STRAWN	11,027	2,476	52,391	-	104	127	107,357	-	-	173,483	6.3
42252826	NOLAN	-100.6000	32.1900	STRAWN	2,696	1,079	27,387	-	1,713	300	48,746	-	-	81,921	7.0
42252827	NOLAN	-100.6000	32.1900	STRAWN	162	241	6,087	-	503	371	9,794	-	-	17,158	7.1
42252828	NOLAN	-100.6000	32.1900	STRAWN	1,079	357	8,109	-	568	408	14,771	-	-	25,293	6.8
42252829	NOLAN	-100.6000	32.1900	STRAWN	11,461	2,196	52,233	-	150	84	107,058	-	-	173,182	6.2
42256538	NOLAN	-100.6300	32.1800	STRAWN	11,708	1,709	40,693	-	319	134	88,132	-	-	142,695	6.4
42256541	NOLAN	-100.6400	32.1800	STRAWN	3,541	775	38,503	-	1,278	291	66,779	-	-	111,167	7.3
42256547	NOLAN	-100.6300	32.1700	STRAWN	8,216	1,421	45,623	-	279	189	88,710	-	-	144,439	6.4
42256550	NOLAN	-100.6300	32.1600	STRAWN	4,847	948	27,532	-	230	257	53,575	-	-	87,497	7.0
42256560	NOLAN	-100.6400	32.1800	STRAWN	4,108	814	26,894	-	917	227	50,399	-	-	83,382	6.4
42256566	NOLAN	-100.6100	32.1800	STRAWN	4,122	902	50,159	-	143	167	87,055	-	-	142,547	6.1
42256575	NOLAN	-100.6300	32.1400	STRAWN	2,058	731	23,546	-	2,645	380	39,909	-	-	69,270	6.8
42256578	NOLAN	-100.6300	32.1400	STRAWN	2,673	588	16,270	-	130	239	31,400	-	-	51,391	7.2
42256580	NOLAN	-100.6500	32.1800	STRAWN	2,228	751	29,936	-	1,976	219	50,701	-	-	85,811	6.6
42256581	NOLAN	-100.6100	32.1600	STRAWN	11,342	2,105	54,793	-	159	91	110,521	-	-	179,012	6.3
42256582	NOLAN	-100.6100	32.1600	STRAWN	11,348	1,780	50,782	-	207	37	103,394	-	-	167,548	7.0
42256584	NOLAN	-100.6200	32.1600	STRAWN	8,118	1,609	46,231	-	172	108	90,152	-	-	146,391	6.0
42256586	NOLAN	-100.6300	32.1700	STRAWN	6,272	1,238	40,373	-	275	155	76,660	-	-	124,973	6.1
**	RUNNELS	-	-	COLEMAN JCT	2,310	1,120	25,700	75.0	4,080	136	41,900	71	-	-	6.9
**	RUNNELS	-99.8330	31.8830	COLEMAN JCT	1,940	1,059	22,500	111.0	2,310	1	38,000	70	-	-	5
**	RUNNELS	-100.0000	31.8830	COLEMAN JCT	2,500	1,122	22,900	80.0	4,170	164	38,300	71	-	-	7.1
**	RUNNELS	-100.0000	31.7000	COLEMAN JCT	4,530	5	31,600	260.0	3,750	985	51,600	93	-	-	11.1
**	RUNNELS	-99.8330	31.6670	-	1,605	1,110	7,440	18.0	3,390	141	15,500	37	-	-	7.5
42003844	SCURRY	-101.0800	32.6700	-	4,378	1,107	34,491	-	1,349	76	63,115	-	-	104,517	5.0
42014408	SCURRY	-	-	-	2,563	748	-3	-	1,461	374	44,964	-	-	75,746	-
42014409	SCURRY	-	-	-	2,676	815	-3	-	1,677	478	48,252	-	-	81,597	-
42105850	SCURRY	-101.0600	32.6000	-	8,738	6,542	44,465	-	1,452	307	101,371	-	-	160,607	6.4
42105860	SCURRY	-101.0600	32.6000	-	11,088	4,768	74,207	-	1,007	337	147,118	-	-	236,768	6.8
42105949	SCURRY	-	-	-	8,397	1,600	29,109	-	850	252	63,651	-	-	101,946	6.8
42252007	SCURRY	-101.0600	32.7500	-	2,729	933	24,833	-	3,420	179	43,672	-	-	76,277	7.6
42003020	SCURRY	-101.0400	32.6800	CADDO STRAWN	10,420	2,312	39,303	-	882	110	85,068	-	-	138,094	7.0
42000071	SCURRY	-101.0100	32.7900	CANYON	10,791	2,309	56,663	-	639	0	112,757	-	-	183,159	5.2
42000097	SCURRY	-101.0200	32.6700	CANYON	2,273	576	18,603	-	2,656	730	32,000	-	-	56,841	7.6
42009277	SCURRY	-100.9600	32.7800	CANYON	3,280	922	29,955	-	2,121	156	53,034	-	-	89,467	-
42009278	SCURRY	-100.9600	32.7800	CANYON	4,872	960	37,083	-	1,121	361	67,698	-	-	112,096	6.8
42009280	SCURRY	-100.9600	32.7800	CANYON	9,864	2,380	65,380	-	592	166	125,378	-	-	203,759	6.1
42009281	SCURRY	-100.9600	32.7800	CANYON	2,541	1,672	44,330	-	816	205	88,462	-	-	138,025	6.6
42009283	SCURRY	-101.0400	32.7200	CANYON	4,851	865	31,894	-	2,031	414	58,530	-	-	98,586	6.5
42019337	SCURRY	-101.0400	32.7200	CANYON	2,602	691	27,296	-	2,201	554	46,764	-	-	80,108	7.0
42253773	SCURRY	-100.9800	32.7000	CANYON	2,679	710	21,824	-	2,483	394	40,506	-	-	66,597	6.6
42252290	SCURRY	-101.0400	32.7200	CANYON LIME	2,246	629	20,253	-	2,453	648	34,853	-	-	61,081	7.3
42000057	SCURRY	-101.0100	32.7300	CANYON REEF	1,740	476	12,040	-	842	314	22,227	-	-	37,640	6.7
42000060	SCURRY	-101.0100	32.7300	CANYON REEF	2,108	551	17,370	-	984	357	31,198	-	-	52,567	7.3
42000061	SCURRY	-101.0100	32.7300	CANYON REEF	1,922	507	16,058	-	925	375	28,749	-	-	48,537	6.9

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42000065	SCURRY	-101.0400	32.7200	CANYON REEF	1,047	192	4,130	-	284	278	8,400	-	-	14,343	7.0
42000067	SCURRY	-101.0400	32.7200	CANYON REEF	4,444	789	18,892	-	483	290	36,700	-	-	61,597	6.5
42000070	SCURRY	-101.0200	32.7700	CANYON REEF	6,416	1,518	44,843	-	716	111	84,362	-	-	137,969	6.2
42000072	SCURRY	-101.0400	32.6600	CANYON REEF	2,337	669	19,614	-	2,404	549	34,237	-	-	59,811	7.2
42000073	SCURRY	-101.0400	32.6600	CANYON REEF	2,417	725	20,368	-	2,364	525	35,746	-	-	62,145	7.3
42000074	SCURRY	-101.0400	32.6600	CANYON REEF	2,338	697	20,186	-	2,400	483	35,248	-	-	61,352	7.1
42000075	SCURRY	-101.0200	32.7300	CANYON REEF	4,544	1,083	24,076	-	655	224	47,715	-	-	78,295	6.4
42000076	SCURRY	-101.0200	32.7300	CANYON REEF	3,991	918	20,860	-	627	278	41,292	-	-	67,965	6.6
42000094	SCURRY	-100.9800	32.6400	CANYON REEF	4,661	750	22,951	-	2,177	263	44,066	-	-	75,995	7.3
42000096	SCURRY	-101.0200	32.6700	CANYON REEF	2,177	568	18,808	-	2,613	435	32,340	-	-	56,940	7.6
42000098	SCURRY	-101.0200	32.6900	CANYON REEF	2,553	743	23,480	-	2,283	331	41,022	-	-	70,412	7.5
42000099	SCURRY	-101.0300	32.6900	CANYON REEF	2,504	699	21,716	-	2,318	555	37,925	-	-	65,717	6.5
42000100	SCURRY	-101.0300	32.6900	CANYON REEF	2,365	666	20,902	-	2,337	525	36,327	-	-	63,122	6.6
42000101	SCURRY	-101.0100	32.7000	CANYON REEF	2,694	735	23,472	-	2,172	415	41,269	-	-	70,756	7.0
42000102	SCURRY	-101.0200	32.6600	CANYON REEF	2,339	560	16,646	-	937	870	30,240	-	-	51,592	7.1
42000103	SCURRY	-101.0600	32.7000	CANYON REEF	4,523	987	45,734	-	1,279	248	80,337	-	-	133,108	6.6
42000106	SCURRY	-101.0500	32.6700	CANYON REEF	3,872	654	17,928	-	2,440	669	34,222	-	-	59,785	6.9
42000108	SCURRY	-101.0000	32.6900	CANYON REEF	2,400	798	23,644	-	2,293	310	41,270	-	-	70,547	6.7
42000109	SCURRY	-101.0000	32.6900	CANYON REEF	2,467	677	21,235	-	2,457	330	37,091	-	-	64,258	7.2
42000110	SCURRY	-101.0200	32.6800	CANYON REEF	2,238	612	22,089	-	2,305	133	38,029	-	-	65,406	7.0
42000115	SCURRY	-101.0300	32.7700	CANYON REEF	6,466	1,547	55,800	-	679	31	85,986	-	-	150,508	5.7
42000116	SCURRY	-101.0300	32.7500	CANYON REEF	4,186	1,154	35,536	-	1,166	183	64,617	-	-	106,843	7.3
42000118	SCURRY	-101.0300	32.7500	CANYON REEF	725	218	6,029	-	585	181	10,681	-	-	18,418	7.4
42000120	SCURRY	-101.0400	32.7500	CANYON REEF	5,894	1,485	40,600	-	800	78	76,747	-	-	125,605	7.9
42000121	SCURRY	-101.0400	32.7500	CANYON REEF	5,527	1,389	38,662	-	854	170	72,737	-	-	119,339	7.0
42000122	SCURRY	-101.0300	32.7200	CANYON REEF	1,778	429	12,276	-	706	308	22,632	-	-	38,129	6.9
42000125	SCURRY	-101.0300	32.7200	CANYON REEF	1,342	317	8,460	-	587	287	15,745	-	-	26,737	6.9
42000126	SCURRY	-101.0000	32.7000	CANYON REEF	2,607	690	23,093	-	2,361	458	38,431	-	-	67,019	7.2
42000128	SCURRY	-101.0400	32.7200	CANYON REEF	4,840	1,171	33,872	-	980	156	63,411	-	-	104,431	6.0
42000131	SCURRY	-101.0400	32.7100	CANYON REEF	3,070	981	29,176	-	1,349	201	52,198	-	-	86,977	6.6
42000133	SCURRY	-101.0300	32.7300	CANYON REEF	8,320	1,704	41,643	-	925	31	83,228	-	-	135,840	6.8
42000134	SCURRY	-101.0300	32.7400	CANYON REEF	9,942	1,010	31,667	-	1,317	85	57,064	-	-	94,701	6.5
42000136	SCURRY	-101.0400	32.7400	CANYON REEF	4,961	1,184	34,609	-	1,091	200	65,024	-	-	107,283	7.0
42000150	SCURRY	-101.0400	32.7200	CANYON REEF	3,299	852	15,325	-	502	315	31,400	-	-	51,692	7.0
42000151	SCURRY	-101.0900	32.7100	CANYON REEF	8,994	1,910	46,372	-	535	72	92,573	-	-	150,456	6.2
42000158	SCURRY	-101.0700	32.7100	CANYON REEF	8,057	1,704	35,216	-	659	104	72,998	-	-	118,349	6.0
42000159	SCURRY	-101.0700	32.7100	CANYON REEF	7,099	1,643	35,976	-	610	139	72,214	-	-	117,035	6.3
42000162	SCURRY	-101.0700	32.7100	CANYON REEF	5,558	1,197	28,388	-	664	209	56,498	-	-	92,513	6.9
42000163	SCURRY	-101.0800	32.7100	CANYON REEF	2,489	662	23,541	-	1,267	381	41,492	-	-	69,833	6.9
42000164	SCURRY	-101.0800	32.7100	CANYON REEF	2,830	831	29,819	-	1,418	305	52,201	-	-	87,404	6.9
42000165	SCURRY	-101.0800	32.7100	CANYON REEF	2,623	965	27,242	-	1,356	224	47,715	-	-	79,913	6.2
42000166	SCURRY	-101.0800	32.7100	CANYON REEF	2,519	667	25,925	-	1,274	326	45,263	-	-	75,975	6.8
42001470	SCURRY	-101.0400	32.7100	CANYON REEF	2,947	894	28,023	-	1,491	339	49,753	-	-	83,447	6.6
42001471	SCURRY	-101.0400	32.7100	CANYON REEF	5,760	1,583	29,753	-	1,017	268	60,099	-	-	98,841	6.9
42001472	SCURRY	-101.0400	32.7200	CANYON REEF	4,268	1,058	33,391	-	1,207	145	61,172	-	-	101,241	6.5
42001474	SCURRY	-101.0400	32.7200	CANYON REEF	3,987	1,036	32,067	-	1,267	149	58,523	-	-	97,029	6.9
42001477	SCURRY	-101.0600	32.6700	CANYON REEF	2,735	760	37,476	-	2,138	487	63,001	-	-	106,598	6.4
42001479	SCURRY	-101.0600	32.6800	CANYON REEF	2,577	716	26,026	-	1,916	394	45,156	-	-	76,786	7.2
42001480	SCURRY	-101.0600	32.6800	CANYON REEF	2,776	762	27,004	-	1,977	387	47,102	-	-	80,009	6.8
42001481	SCURRY	-101.0600	32.6800	CANYON REEF	2,894	909	27,489	-	1,956	345	48,529	-	-	82,121	6.9
42001482	SCURRY	-101.0600	32.6800	CANYON REEF	2,769	940	26,725	-	1,843	351	47,298	-	-	79,925	7.0

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42001483	SCURRY	-101.0600	32.6800	CANYON REEF	2,840	859	26,536	-	1,914	442	46,795	-	-	75,177	7.1
42001485	SCURRY	-101.0400	32.7300	CANYON REEF	4,524	1,062	24,273	-	546	236	44,755	-	-	73,296	6.7
42001486	SCURRY	-101.0800	32.7100	CANYON REEF	7,773	1,525	45,917	-	658	96	88,491	-	-	144,459	6.7
42001497	SCURRY	-101.0500	32.6800	CANYON REEF	2,578	693	22,631	-	2,345	466	39,487	-	-	68,199	7.5
42001500	SCURRY	-101.0500	32.7200	CANYON REEF	473	116	2,386	-	6	453	4,587	-	-	8,020	7.2
42001505	SCURRY	-101.0500	32.7200	CANYON REEF	538	127	3,202	-	217	630	5,735	-	-	10,447	7.0
42001511	SCURRY	-101.0600	32.6900	CANYON REEF	5,551	1,346	28,329	-	480	345	56,887	-	-	92,937	6.8
42001514	SCURRY	-101.0600	32.6900	CANYON REEF	5,531	1,326	37,726	-	1,038	211	70,956	-	-	116,789	6.7
42001516	SCURRY	-101.0500	32.6800	CANYON REEF	2,739	778	25,424	-	2,048	466	44,549	-	-	76,003	7.1
42001518	SCURRY	-101.0100	32.7200	CANYON REEF	2,312	703	18,562	-	1,092	364	33,747	-	-	56,779	7.1
42001578	SCURRY	-100.9100	32.8200	CANYON REEF	12,569	2,160	38,694	-	768	262	86,111	-	-	140,125	6.1
42002969	SCURRY	-101.0100	32.7300	CANYON REEF	3,291	771	21,258	-	712	276	40,163	-	-	66,471	6.8
42002996	SCURRY	-101.0200	32.7100	CANYON REEF	1,003	170	4,318	-	275	378	8,505	-	-	14,649	6.8
42003002	SCURRY	-101.0300	32.7100	CANYON REEF	3,176	769	25,663	-	1,134	342	46,400	-	-	77,485	-
42003005	SCURRY	-101.0000	32.7300	CANYON REEF	3,021	753	24,325	-	1,352	280	44,117	-	-	74,098	7.2
42003006	SCURRY	-101.0300	32.7200	CANYON REEF	7,230	1,779	29,896	-	698	155	63,717	-	-	103,745	6.9
42003007	SCURRY	-101.0200	32.7200	CANYON REEF	4,551	1,101	24,975	-	749	251	49,243	-	-	81,060	7.0
42003010	SCURRY	-101.0500	32.7200	CANYON REEF	7,331	1,420	28,898	-	652	173	61,303	-	-	100,022	6.9
42003011	SCURRY	-101.0600	32.7200	CANYON REEF	3,202	603	14,040	-	486	263	28,641	-	-	47,321	7.2
42003019	SCURRY	-101.0300	32.6700	CANYON REEF	2,139	629	19,032	-	2,251	446	33,047	-	-	57,544	7.3
42003021	SCURRY	-101.0200	32.7200	CANYON REEF	4,511	1,084	21,903	-	679	257	44,419	-	-	73,023	7.1
42003022	SCURRY	-101.0400	32.7100	CANYON REEF	7,260	1,818	35,066	-	1,215	221	71,558	-	-	117,548	6.3
42003024	SCURRY	-101.0400	32.7100	CANYON REEF	5,786	1,158	30,092	-	721	1,181	58,903	-	-	97,718	7.1
42003025	SCURRY	-101.0100	32.7200	CANYON REEF	2,396	462	19,311	-	972	376	34,426	-	-	57,944	6.7
42003026	SCURRY	-101.0100	32.7200	CANYON REEF	2,591	641	20,415	-	1,063	348	36,958	-	-	62,016	7.0
42003027	SCURRY	-101.0600	32.7100	CANYON REEF	8,620	1,975	38,407	-	591	185	80,000	-	-	130,128	6.6
42003028	SCURRY	-101.0600	32.6700	CANYON REEF	2,477	666	21,653	-	2,418	483	37,663	-	-	65,359	7.3
42003031	SCURRY	-101.0000	32.7300	CANYON REEF	1,946	446	12,832	-	624	281	23,909	-	-	40,037	6.9
42003034	SCURRY	-101.0000	32.7000	CANYON REEF	2,333	630	20,839	-	2,356	268	36,215	-	-	62,641	-
42003037	SCURRY	-101.0500	32.6600	CANYON REEF	1,995	585	17,745	-	2,514	160	30,650	-	-	53,649	-
42003038	SCURRY	-101.0500	32.6600	CANYON REEF	2,296	579	17,684	-	2,662	495	30,782	-	-	54,499	7.1
42003039	SCURRY	-101.0100	32.7400	CANYON REEF	2,307	566	18,259	-	1,015	271	32,980	-	-	55,399	6.8
42005023	SCURRY	-100.9600	32.6700	CANYON REEF	2,660	741	26,000	-	2,210	385	45,100	-	-	77,096	-
42005024	SCURRY	-101.0200	32.7700	CANYON REEF	6,210	1,600	45,400	-	719	149	85,100	-	-	139,178	-
42005098	SCURRY	-101.0600	32.7000	CANYON REEF	672	105	2,673	-	218	362	5,251	-	-	9,281	7.4
42005117	SCURRY	-101.0200	32.7600	CANYON REEF	5,941	1,447	40,141	-	864	22	75,996	-	-	124,411	6.0
42007255	SCURRY	-100.9600	32.7800	CANYON REEF	6,394	1,465	49,732	-	867	267	91,484	-	-	150,207	-
42007256	SCURRY	-100.9600	32.7800	CANYON REEF	3,734	1,056	32,148	-	1,454	306	58,037	-	-	96,734	-
42007257	SCURRY	-100.9600	32.7800	CANYON REEF	2,730	797	25,410	-	2,236	466	44,415	-	-	76,054	-
42007422	SCURRY	-100.6600	32.8600	CANYON REEF	2,358	728	21,480	-	2,400	89	37,594	-	-	64,649	6.9
42007424	SCURRY	-100.6600	32.8600	CANYON REEF	12,398	2,301	54,818	-	238	51	113,032	-	-	182,771	6.1
42007434	SCURRY	-100.6600	32.8600	CANYON REEF	2,097	305	6,916	-	729	176	14,417	-	-	24,819	7.5
42014406	SCURRY	-	-	CANYON REEF	4,257	832	-3	-	1,869	323	49,784	-	-	83,898	-
42014407	SCURRY	-	-	CANYON REEF	4,758	929	-3	-	1,388	362	56,642	-	-	91,935	-
42018449	SCURRY	-101.0400	32.7200	CANYON REEF	2,642	758	22,862	-	2,268	394	40,282	-	-	69,230	7.0
42018450	SCURRY	-101.0400	32.7200	CANYON REEF	2,685	778	24,384	-	2,143	356	42,845	-	-	73,191	7.0
42018467	SCURRY	-100.9600	32.7800	CANYON REEF	2,659	724	23,659	-	2,239	73	41,615	-	-	70,967	7.9
42018468	SCURRY	-100.9600	32.7800	CANYON REEF	2,778	783	23,666	-	2,133	38	45,816	-	-	75,236	8.2
42018474	SCURRY	-100.9600	32.7800	CANYON REEF	3,164	943	30,518	-	1,377	286	54,240	-	-	90,529	6.9
42018477	SCURRY	-100.9600	32.7800	CANYON REEF	3,328	1,007	30,162	-	1,388	478	54,034	-	-	90,333	6.6
42018479	SCURRY	-100.9600	32.7800	CANYON REEF	3,435	1,031	29,708	-	1,511	286	53,627	-	-	89,596	6.8

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42018482	SCURRY	-100.9600	32.7800	CANYON REEF	3,197	703	14,367	-	508	387	29,260	-	-	48,421	6.8
42251986	SCURRY	-101.0000	32.7400	CANYON REEF	1,612	430	12,998	-	869	209	23,392	-	-	39,509	7.5
42251987	SCURRY	-101.0000	32.7400	CANYON REEF	2,120	586	17,554	-	1,014	321	31,604	-	-	54,234	6.7
42251988	SCURRY	-101.0000	32.7400	CANYON REEF	2,946	839	25,630	-	1,270	295	46,083	-	-	77,063	6.6
42251989	SCURRY	-101.0000	32.7400	CANYON REEF	3,414	1,083	30,510	-	1,465	214	55,055	-	-	91,743	6.3
42251990	SCURRY	-101.0600	32.7000	CANYON REEF	3,744	802	37,509	-	1,294	375	65,654	-	-	109,378	6.9
42252001	SCURRY	-101.0600	32.6900	CANYON REEF	6,703	1,681	34,489	-	501	98	69,532	-	-	113,004	6.5
42252002	SCURRY	-101.0600	32.6900	CANYON REEF	2,403	578	11,753	-	412	298	23,593	-	-	39,038	7.2
42252003	SCURRY	-101.0600	32.6900	CANYON REEF	5,219	1,265	26,630	-	451	324	53,475	-	-	87,364	-
42252004	SCURRY	-101.0600	32.6900	CANYON REEF	5,130	1,230	34,990	-	963	196	65,810	-	-	108,319	-
42252005	SCURRY	-101.0600	32.6900	CANYON REEF	3,546	829	31,725	-	1,271	334	56,498	-	-	94,203	7.0
42252010	SCURRY	-101.0100	32.7000	CANYON REEF	2,875	723	23,722	-	2,290	305	41,922	-	-	71,838	6.8
42252011	SCURRY	-101.0100	32.7000	CANYON REEF	2,778	783	23,666	-	2,133	38	45,818	-	-	75,236	8.2
42252019	SCURRY	-101.0000	32.7000	CANYON REEF	2,659	724	23,659	-	2,233	73	41,615	-	-	70,970	7.9
42252021	SCURRY	-101.0400	32.6800	CANYON REEF	2,668	661	21,660	-	2,030	578	38,298	-	-	65,897	7.6
42252022	SCURRY	-101.0400	32.6800	CANYON REEF	1,635	535	16,558	-	2,360	508	28,046	-	-	49,644	7.2
42252023	SCURRY	-101.0500	32.7100	CANYON REEF	5,917	1,282	29,231	-	590	248	58,723	-	-	95,991	6.6
42252024	SCURRY	-101.0500	32.7100	CANYON REEF	3,806	773	17,026	-	590	328	34,629	-	-	57,153	6.9
42252025	SCURRY	-101.0600	32.7100	CANYON REEF	6,626	1,490	32,538	-	633	197	65,927	-	-	107,712	6.5
42252026	SCURRY	-101.0500	32.6800	CANYON REEF	2,342	765	22,388	-	2,334	416	38,943	-	-	67,189	7.1
42252027	SCURRY	-101.0600	32.7200	CANYON REEF	6,091	1,353	29,640	-	538	192	59,936	-	-	97,751	6.6
42252028	SCURRY	-101.0500	32.7200	CANYON REEF	3,504	648	15,391	-	606	275	31,257	-	-	51,766	6.8
42252029	SCURRY	-101.0500	32.7200	CANYON REEF	3,003	621	12,176	-	535	387	25,284	-	-	42,008	6.7
42252030	SCURRY	-101.0500	32.7200	CANYON REEF	5,674	1,031	26,962	-	600	248	54,035	-	-	88,551	6.5
42252031	SCURRY	-101.0500	32.7200	CANYON REEF	4,484	983	20,204	-	546	278	41,391	-	-	67,884	6.6
42252032	SCURRY	-101.0500	32.7200	CANYON REEF	3,266	709	15,054	-	501	348	30,497	-	-	50,376	6.9
42252033	SCURRY	-101.0500	32.7100	CANYON REEF	6,203	1,232	28,260	-	607	292	57,688	-	-	94,462	6.8
42252038	SCURRY	-101.0300	32.7500	CANYON REEF	672	202	5,586	-	542	167	9,896	-	-	17,065	7.4
42252039	SCURRY	-101.0300	32.7600	CANYON REEF	6,309	1,595	41,390	-	752	97	79,044	-	-	129,188	6.5
42252045	SCURRY	-101.0300	32.6900	CANYON REEF	4,661	750	22,951	-	2,177	263	44,066	-	-	74,868	7.3
42252048	SCURRY	-101.0500	32.6700	CANYON REEF	2,271	702	20,319	-	2,432	616	35,253	-	-	61,594	6.9
42252049	SCURRY	-101.0400	32.6900	CANYON REEF	2,642	758	22,883	-	2,268	394	40,282	-	-	69,228	7.0
42252050	SCURRY	-101.0400	32.6800	CANYON REEF	2,801	840	23,879	-	2,129	330	42,476	-	-	72,455	6.8
42252051	SCURRY	-101.0300	32.6900	CANYON REEF	2,365	662	21,281	-	2,384	543	36,855	-	-	64,090	7.2
42252057	SCURRY	-101.0100	32.7400	CANYON REEF	4,977	1,145	33,407	-	1,157	88	62,770	-	-	103,545	6.0
42252062	SCURRY	-101.0000	32.7000	CANYON REEF	2,617	804	24,184	-	2,230	189	42,525	-	-	72,550	7.9
42252064	SCURRY	-101.0300	32.7200	CANYON REEF	4,994	738	27,161	-	694	221	52,246	-	-	86,054	6.9
42252066	SCURRY	-101.0400	32.7100	CANYON REEF	2,193	1,284	43,574	-	1,956	338	73,201	-	-	122,547	6.9
42252071	SCURRY	-101.0300	32.7100	CANYON REEF	2,967	715	21,719	-	966	280	39,963	-	-	66,611	6.7
42252073	SCURRY	-101.0100	32.7200	CANYON REEF	2,044	625	16,635	-	997	340	30,349	-	-	51,205	7.1
42252278	SCURRY	-100.9600	32.7800	CANYON REEF	2,428	732	23,894	-	2,323	290	41,709	-	-	71,556	6.9
42252281	SCURRY	-100.6600	32.8600	CANYON REEF	12,398	2,301	54,818	-	238	51	112,964	-	-	182,772	6.1
42252284	SCURRY	-100.9600	32.7800	CANYON REEF	4,171	1,588	32,675	-	2,136	155	65,456	-	-	106,181	7.0
42252285	SCURRY	-	-	CANYON REEF	2,534	648	16,552	-	419	393	31,449	-	-	51,995	7.0
42252289	SCURRY	-101.0400	32.7200	CANYON REEF	6,352	973	34,070	-	1,135	686	65,395	-	-	108,612	6.2
42252291	SCURRY	-100.9600	32.7800	CANYON REEF	4,008	1,158	23,100	-	856	102	45,627	-	-	75,105	6.1
42253730	SCURRY	-101.0100	32.7200	CANYON REEF	691	139	3,605	-	429	417	6,626	-	-	11,907	7.1
42253732	SCURRY	-101.0100	32.7300	CANYON REEF	2,721	767	22,826	-	1,207	309	41,190	-	-	69,021	6.6
42253734	SCURRY	-101.0100	32.7300	CANYON REEF	2,422	670	19,868	-	1,085	326	35,885	-	-	60,258	6.7
42253736	SCURRY	-101.0400	32.7100	CANYON REEF	2,883	937	28,256	-	1,453	319	50,159	-	-	84,007	6.6
42253739	SCURRY	-101.0400	32.7100	CANYON REEF	5,144	1,083	28,275	-	675	288	55,188	-	-	90,653	6.6

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42253743	SCURRY	-101.0400	32.7100	CANYON REEF	5,975	1,307	35,824	-	1,152	150	68,705	-	-	113,113	6.6
42253744	SCURRY	-101.0400	32.7100	CANYON REEF	1,106	219	4,673	-	275	278	9,441	-	-	15,992	6.8
42253751	SCURRY	-101.0100	32.7200	CANYON REEF	2,313	446	18,635	-	938	363	33,220	-	-	55,915	6.7
42253756	SCURRY	-101.0200	32.7800	CANYON REEF	9,147	1,896	49,538	-	493	24	97,747	-	-	158,847	5.9
42253759	SCURRY	-101.0300	32.7300	CANYON REEF	5,255	1,342	36,993	-	1,015	111	69,458	-	-	114,174	6.4
42253765	SCURRY	-101.0500	32.6600	CANYON REEF	2,071	607	18,425	-	2,610	166	31,824	-	-	55,704	7.0
42253768	SCURRY	-100.9900	32.7200	CANYON REEF	3,112	839	28,718	-	1,672	246	50,851	-	-	85,438	6.7
42253777	SCURRY	-101.0400	32.7200	CANYON REEF	5,337	1,139	27,052	-	673	220	53,865	-	-	88,286	6.9
42253778	SCURRY	-101.0200	32.7300	CANYON REEF	4,264	964	28,896	-	856	225	54,149	-	-	89,354	6.3
42253780	SCURRY	-101.0900	32.7100	CANYON REEF	9,066	1,941	48,772	-	594	79	96,444	-	-	156,896	5.9
42253788	SCURRY	-101.0900	32.7000	CANYON REEF	7,832	1,582	46,022	-	692	91	88,901	-	-	145,121	6.2
42253790	SCURRY	-101.0800	32.7100	CANYON REEF	2,464	729	28,993	-	1,578	327	49,851	-	-	83,942	6.8
42253791	SCURRY	-101.0800	32.7000	CANYON REEF	1,805	319	8,847	-	493	272	17,230	-	-	28,984	7.1
42253792	SCURRY	-101.0000	32.7400	CANYON REEF	2,746	856	21,600	-	1,000	284	39,760	-	-	66,247	7.1
42253794	SCURRY	-101.0400	32.7200	CANYON REEF	4,572	907	21,047	-	562	328	42,710	-	-	70,271	6.9
42253800	SCURRY	-101.0700	32.7000	CANYON REEF	7,101	1,504	34,754	-	669	212	69,938	-	-	114,178	6.6
42253802	SCURRY	-101.0700	32.7000	CANYON REEF	6,868	1,538	34,272	-	661	163	68,917	-	-	112,420	6.5
42253805	SCURRY	-101.0500	32.7200	CANYON REEF	454	104	2,105	-	133	375	4,039	-	-	7,211	7.3
42253806	SCURRY	-101.0500	32.7200	CANYON REEF	462	123	2,234	-	135	417	4,282	-	-	7,654	7.3
42253808	SCURRY	-101.0500	32.7200	CANYON REEF	474	102	2,185	-	145	327	4,179	-	-	7,436	7.4
42253809	SCURRY	-101.0400	32.7200	CANYON REEF	3,328	1,007	30,162	-	1,388	478	54,034	-	-	90,397	6.6
42253812	SCURRY	-101.0500	32.6700	CANYON REEF	2,217	684	21,444	-	2,553	438	36,840	-	-	64,176	7.3
42253813	SCURRY	-101.0400	32.6600	CANYON REEF	3,920	660	19,455	-	2,364	279	36,963	-	-	63,640	7.7
42255476	SCURRY	-101.0400	32.6700	CANYON REEF	2,975	1,169	29,856	-	3,857	527	51,744	-	-	90,128	7.2
42255481	SCURRY	-101.0000	32.6900	CANYON REEF	6,841	843	23,097	-	2,034	340	48,477	-	-	81,632	7.3
42255484	SCURRY	-101.0200	32.6800	CANYON REEF	2,217	664	19,582	-	2,259	405	34,155	-	-	59,282	6.7
42255489	SCURRY	-101.0400	32.6700	CANYON REEF	4,367	1,052	28,275	-	2,053	302	52,713	-	-	88,762	7.2
42255760	SCURRY	-100.9100	32.8200	CANYON REEF	5,384	1,088	27,171	-	1,150	275	53,586	-	-	88,653	6.8
42256589	SCURRY	-101.0500	32.6700	CANYON REEF	3,287	972	25,183	-	1,791	417	45,836	-	-	77,487	7.2
42256590	SCURRY	-101.0400	32.6700	CANYON REEF	2,457	714	22,585	-	2,279	415	39,315	-	-	67,765	7.1
42256592	SCURRY	-101.0300	32.6700	CANYON REEF	2,372	705	21,214	-	2,341	610	36,888	-	-	64,132	7.6
42256593	SCURRY	-101.0300	32.6700	CANYON REEF	2,489	721	21,757	-	2,270	581	38,074	-	-	65,892	7.3
42252036	SCURRY	-101.0600	32.6800	CANYON SAND	2,446	846	25,221	-	2,092	195	44,041	-	-	74,842	7.0
42253752	SCURRY	-101.0600	32.6700	CANYON SAND	2,404	737	21,886	-	2,367	494	38,129	-	-	66,017	7.0
42253811	SCURRY	-100.9200	32.8200	CANYON SAND	2,384	511	16,481	-	1,230	249	30,048	-	-	50,925	6.8
42255473	SCURRY	-100.9200	32.8200	CISCO	5,671	1,139	28,969	-	101	110	57,886	-	-	93,876	6.3
42255474	SCURRY	-100.9200	32.8200	CISCO	11,017	2,214	46,790	-	174	134	97,881	-	-	158,210	6.2
42009274	SCURRY	-101.0600	32.6000	CLEAR FORK	5,780	2,319	43,850	-	1,670	290	83,084	-	-	136,994	8.1
42009275	SCURRY	-101.0400	32.7200	CLEAR FORK	2,466	1,076	30,838	-	5,123	182	51,234	-	-	90,920	7.2
42000095	SCURRY	-101.1000	32.7800	ELLENBURGER	1,677	509	17,659	-	2,018	41	30,171	-	-	52,074	7.7
42000104	SCURRY	-101.0900	32.7800	ELLENBURGER	1,877	450	16,971	-	2,193	70	29,143	-	-	50,705	7.7
42001412	SCURRY	-101.0900	32.7800	ELLENBURGER	1,820	500	17,768	-	2,265	207	30,281	-	-	52,840	7.4
42001413	SCURRY	-101.0900	32.7800	ELLENBURGER	1,908	431	17,556	-	2,701	718	29,294	-	-	52,609	7.3
42003013	SCURRY	-101.1000	32.7900	ELLENBURGER	4,627	1,304	36,264	-	623	550	65,138	-	-	111,134	6.5
42003154	SCURRY	-100.9400	32.6500	ELLENBURGER	1,560	500	18,519	-	2,100	195	31,900	-	-	55,278	7.3
42003156	SCURRY	-100.7500	32.8300	ELLENBURGER	3,064	194	28,037	-	2,275	519	47,250	-	-	81,339	-
42006818	SCURRY	-101.1000	32.7900	ELLENBURGER	2,417	785	23,533	-	3,822	232	39,902	-	-	70,692	7.8
42009273	SCURRY	-	-	ELLENBURGER	1,983	519	14,800	-	1,599	766	26,206	-	-	45,873	8.2
42018278	SCURRY	-101.1000	32.7900	ELLENBURGER	1,840	456	17,650	-	2,033	602	29,950	-	-	52,531	6.9
42018370	SCURRY	-101.1000	32.7900	ELLENBURGER	1,978	493	19,187	-	2,441	632	32,360	-	-	57,092	7.2
42018457	SCURRY	-	-	ELLENBURGER	1,766	465	18,355	-	2,001	592	30,962	-	-	54,140	7.4

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42003014	SCURRY	-101.0700	32.7300	GLORIETA	1,830	913	27,723	-	3,264	255	46,061	-	-	80,070	7.9
42003030	SCURRY	-101.0600	32.8100	GLORIETA	2,343	674	20,940	-	3,400	194	35,775	-	-	63,324	6.6
42006815	SCURRY	-101.0700	32.8500	GLORIETA	2,584	983	22,987	-	560	274	40,001	-	-	70,516	7.9
42006816	SCURRY	-101.0700	32.8500	GLORIETA	2,490	846	23,954	-	3,266	202	41,277	-	-	72,036	7.4
42006819	SCURRY	-101.0700	32.8500	GLORIETA	2,480	804	23,787	-	3,399	178	40,795	-	-	71,443	7.6
42007364	SCURRY	-101.0700	32.8500	GLORIETA	2,456	914	25,898	-	3,077	376	44,455	-	-	77,176	8.3
42007365	SCURRY	-101.0700	32.8500	GLORIETA	2,918	1,021	25,445	-	3,394	167	45,217	-	-	78,651	7.7
42007366	SCURRY	-101.0700	32.8500	GLORIETA	3,043	1,042	26,703	-	3,369	131	47,587	-	-	82,483	7.4
42007367	SCURRY	-101.0700	32.8500	GLORIETA	2,475	809	24,597	-	3,367	240	42,044	-	-	73,533	7.8
42007368	SCURRY	-101.0700	32.8500	GLORIETA	2,603	905	23,751	-	3,393	293	41,608	-	-	73,014	7.4
42007369	SCURRY	-101.0700	32.8500	GLORIETA	2,856	996	26,276	-	3,350	150	45,912	-	-	79,540	7.5
42007373	SCURRY	-101.0700	32.8500	GLORIETA	2,228	983	24,342	-	3,109	242	41,902	-	-	72,806	7.7
42007379	SCURRY	-101.0700	32.8500	GLORIETA	2,528	706	21,416	-	3,437	338	36,821	-	-	65,246	7.0
42007382	SCURRY	-101.0700	32.8500	GLORIETA	2,304	671	22,079	-	3,480	461	37,240	-	-	66,234	7.5
42007384	SCURRY	-101.0700	32.8500	GLORIETA	2,342	752	21,439	-	3,389	363	36,686	-	-	64,972	8.1
42007385	SCURRY	-101.0700	32.8500	GLORIETA	2,589	914	27,407	-	3,447	194	46,847	-	-	81,397	8.2
42007387	SCURRY	-101.0700	32.8500	GLORIETA	2,190	693	23,907	-		51	39,990	-	-	-3	8.0
42007389	SCURRY	-101.0700	32.8500	GLORIETA	2,654	810	25,008	-		442	43,149	-	-	-3	7.4
42007391	SCURRY	-101.0700	32.8500	GLORIETA	3,131	1,278	29,495	-	3,037	261	52,347	-	-	89,549	7.5
42007392	SCURRY	-101.0700	32.8500	GLORIETA	2,848	1,005	26,180	-	3,357	155	46,229	-	-	80,283	7.5
42007393	SCURRY	-101.0700	32.8500	GLORIETA	2,247	1,086	24,568	-	2,592	309	42,933	-	-	73,735	8.3
42007394	SCURRY	-101.0700	32.8500	GLORIETA	2,398	1,104	28,092	-	3,204	146	48,331	-	-	83,275	7.6
42007402	SCURRY	-101.0700	32.8500	GLORIETA	2,474	914	24,042	-	3,367	352	41,425	-	-	72,573	8.5
42007403	SCURRY	-101.0700	32.8500	GLORIETA	2,493	983	26,382	-	3,180	207	46,269	-	-	79,514	8.3
42007404	SCURRY	-101.0700	32.8500	GLORIETA	2,381	1,005	23,792	-	2,911	352	41,424	-	-	71,912	8.8
42007406	SCURRY	-101.0700	32.8500	GLORIETA	2,698	906	25,917	-	3,262	220	44,842	-	-	77,846	7.4
42007408	SCURRY	-101.0700	32.8500	GLORIETA	2,783	981	23,750	-	3,280	141	41,900	-	-	72,834	7.4
42007432	SCURRY	-101.0700	32.8500	GLORIETA	2,262	580	21,044	-	3,553	587	35,180	-	-	63,206	7.4
42007433	SCURRY	-101.0700	32.8500	GLORIETA	2,354	752	22,459	-	3,620	313	38,135	-	-	67,633	7.7
42007435	SCURRY	-101.0700	32.8500	GLORIETA	2,684	994	27,105	-	2,897	351	47,096	-	-	81,128	7.7
42007437	SCURRY	-101.0700	32.8500	GLORIETA	2,651	809	24,153	-	2,997	109	41,944	-	-	72,723	7.9
42007438	SCURRY	-101.0700	32.8500	GLORIETA	2,828	1,001	26,241	-	2,933	961	45,879	-	-	79,211	7.6
42007439	SCURRY	-101.0700	32.8500	GLORIETA	2,960	1,106	25,869	-	3,245	179	46,348	-	-	80,253	7.2
42007441	SCURRY	-101.0700	32.8500	GLORIETA	3,064	728	24,175	-	3,129	0	42,849	-	-	74,589	8.7
42007442	SCURRY	-101.0700	32.8500	GLORIETA	2,897	1,020	25,738	-	3,327	143	45,732	-	-	79,388	7.4
42007444	SCURRY	-101.0700	32.8500	GLORIETA	2,814	990	25,806	-	3,436	132	45,525	-	-	79,233	7.2
42007445	SCURRY	-101.0700	32.8500	GLORIETA	2,513	924	26,087	-	3,248	243	44,829	-	-	77,844	8.1
42007446	SCURRY	-101.0700	32.8500	GLORIETA	2,771	957	25,646	-	3,417	167	45,116	-	-	78,622	7.5
42007447	SCURRY	-101.0700	32.8500	GLORIETA	2,589	925	26,219	-	2,180	97	45,241	-	-	78,327	7.9
42018448	SCURRY	-101.0700	32.8500	GLORIETA	2,940	1,162	26,820	-	3,246	202	47,435	-	-	81,803	7.9
42018463	SCURRY	-101.0700	32.8500	GLORIETA	2,460	863	22,779	-	3,631	185	39,598	-	-	69,947	7.6
42018464	SCURRY	-101.0700	32.8500	GLORIETA	2,959	1,124	25,556	-	3,562	119	45,226	-	-	78,547	8.0
42018471	SCURRY	-101.0700	32.8500	GLORIETA	2,900	1,027	24,763	-	3,527	156	43,618	-	-	75,992	8.0
42251969	SCURRY	-101.0600	32.7900	GLORIETA	2,500	773	23,471	-	3,673	269	40,000	-	-	70,687	7.5
42251992	SCURRY	-101.0600	32.7800	GLORIETA	2,786	954	25,898	-	3,476	130	45,501	-	-	79,299	7.4
42251993	SCURRY	-101.0700	32.7900	GLORIETA	2,354	833	22,898	-	3,827	203	39,346	-	-	69,891	-
42251995	SCURRY	-101.0700	32.7800	GLORIETA	2,646	900	22,276	-	3,524	155	43,056	-	-	73,010	7.4
42251997	SCURRY	-101.0700	32.7900	GLORIETA	2,654	810	25,008	-	2,992	442	43,149	-	-	75,055	7.4
42251998	SCURRY	-101.0600	32.7900	GLORIETA	2,415	867	24,953	-	3,764	168	42,850	-	-	75,517	7.6
42252006	SCURRY	-101.0700	32.7500	GLORIETA	2,604	885	23,335	-	3,503	168	40,890	-	-	71,826	7.4
42252017	SCURRY	-101.0600	32.7400	GLORIETA	3,294	1,206	24,370	-	3,094	251	44,908	-	-	77,583	7.2

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42252018	SCURRY	-101.0600	32.7900	GLORIETA	2,254	564	19,428	-	3,113	443	33,034	-	-	58,838	7.5
42252265	SCURRY	-101.0700	32.8500	GLORIETA	2,539	821	24,406	-	3,337	226	41,925	-	-	73,254	7.4
42252268	SCURRY	-101.0700	32.8500	GLORIETA	2,545	957	22,467	-	3,611	142	39,196	-	-	68,919	8.0
42252272	SCURRY	-101.0700	32.8500	GLORIETA	2,856	1,029	26,258	-	3,383	132	46,454	-	-	80,644	7.3
42252275	SCURRY	-101.0700	32.8500	GLORIETA	3,033	1,036	26,291	-	3,359	271	46,288	-	-	80,278	7.3
42253816	SCURRY	-101.0600	32.7900	GLORIETA	2,571	954	24,971	-	3,829	218	42,897	-	-	75,440	7.7
42255491	SCURRY	-101.0600	32.7900	GLORIETA	2,476	859	24,100	-	5,481	385	39,778	-	-	73,079	7.4
42251994	SCURRY	-101.0700	32.7900	GLORIETA SAND	2,215	802	22,708	-	3,672	293	38,793	-	-	68,924	7.5
42251996	SCURRY	-101.0700	32.7900	GLORIETA SAND	2,287	883	23,053	-	3,927	143	39,599	-	-	70,352	7.8
42253814	SCURRY	-101.0600	32.7900	GLORIETA SAND	2,286	906	23,897	-	3,422	423	41,203	-	-	72,619	7.4
42255475	SCURRY	-101.0500	32.7000	LOWER CLEARFORK	5,186	2,621	49,135	-	2,547	100	90,640	-	-	150,229	6.7
42009272	SCURRY	-	-	MISSISSIPPIAN	2,501	821	20,980	-	1,741	339	37,628	-	-	64,011	8.4
42007426	SCURRY	-100.6600	32.8600	OCHO JUAN CANYON REEF	14,736	2,685	63,205	-	183	29	131,200	-	-	212,038	5.8
42003153	SCURRY	-100.9400	32.6500	PENNSYLVANIAN	8,680	1,570	37,109	-	440	110	77,300	-	-	125,540	6.3
42003155	SCURRY	-100.7500	32.8300	PENNSYLVANIAN	1,740	783	17,312	-	3,000	110	30,100	-	-	53,246	7.6
42009271	SCURRY	-	-	PENNSYLVANIAN	5,391	1,003	45,594	-	999	195	82,161	-	-	135,503	6.0
42003033	SCURRY	-101.0900	32.7500	SAN ANDRES	2,036	1,107	21,390	-	4,244	524	36,380	-	-	65,681	-
42009270	SCURRY	-100.9600	32.7800	SAN ANDRES	6,651	2,611	34,286	-	1,319	711	70,742	-	-	116,319	7.3
42251014	SCURRY	-101.0900	32.7500	SAN ANDRES	6,244	4,151	20,812	-	2,200	880	53,100	-	-	87,387	5.8
42255492	SCURRY	-101.0900	32.7500	SAN ANDRES	2,130	1,158	22,385	-	4,441	548	38,072	-	-	68,735	6.3
42003157	SCURRY	-100.7500	32.8300	SPRABERRY	2,270	1,170	27,373	-	4,000	146	47,900	-	-	83,625	6.5
42001580	SCURRY	-100.9100	32.8200	STRAWN	11,043	2,206	51,129	-	491	67	104,411	-	-	169,347	6.7
42003018	SCURRY	-100.9100	32.8200	STRAWN	12,205	2,570	54,347	-	419	54	112,549	-	-	182,143	5.7
42003035	SCURRY	-101.0900	32.6400	STRAWN	2,348	587	17,171	-	2,731	676	29,944	-	-	53,457	-
42003036	SCURRY	-101.0900	32.6400	STRAWN	2,347	526	17,209	-	2,698	688	29,841	-	-	53,309	-
42009267	SCURRY	-	-	STRAWN	1,198	222	51,545	-	1,436	240	81,320	-	-	136,140	6.6
42009269	SCURRY	-100.9300	32.8500	STRAWN	3,201	912	26,818	-	1,648	352	48,230	-	-	81,161	7.1
42251999	SCURRY	-101.0400	32.6800	STRAWN	2,636	209	23,125	-	2,417	667	38,717	-	-	67,772	6.8
42252288	SCURRY	-101.0400	32.7200	STRAWN	2,432	545	17,835	-	2,796	713	30,927	-	-	55,249	6.8
42253817	SCURRY	-101.0900	32.6400	STRAWN	2,433	608	17,793	-	2,830	700	31,028	-	-	55,392	6.6
42002997	STERLING	-100.9800	31.6400	CLEAR FORK	678	175	4,362	-	2,026	199	6,822	-	-	14,262	7.2
42002998	STERLING	-100.9800	31.6400	CLEAR FORK	2,091	961	27,026	-	863	240	47,395	-	-	78,575	6.9
42003004	STERLING	-100.9800	31.6500	CLEAR FORK	508	137	3,569	-	1,795	196	5,359	-	-	11,564	7.1
42007167	STERLING	-101.2400	31.8100	CLEAR FORK	3,052	272	26,582	-	181	600	43,798	-	-	74,834	7.0
42000393	STERLING	-101.1600	32.0400	ELLENBURGER	2,119	429	16,774	-	1,953	684	29,287	-	-	51,527	7.2
42000395	STERLING	-101.1600	32.0400	FUSSELMAN	2,096	433	21,370	-	2,368	569	36,230	-	-	63,436	6.6
42001853	STERLING	-101.0900	31.8100	FUSSELMAN	2,060	427	22,165	-	2,100	403	38,100	-	-	65,782	7.2
42000143	STERLING	-100.9100	32.0200	MISSISSIPPI CHAT	1,190	316	27,272	-	1,720	823	43,335	-	-	74,656	6.8
42000141	STERLING	-100.8200	31.7700	SAN ANGELO	2,463	914	27,691	-	3,502	411	46,899	-	-	81,881	6.7
42005113	STERLING	-100.8200	31.7600	SAN ANGELO	2,470	940	27,783	-	3,815	477	46,879	-	-	82,365	6.8
42250192	STERLING	-101.2600	31.5500	SPRABERRY	480	152	11,099	-	9	354	18,200	-	-	30,294	7.4
42250193	STERLING	-101.2600	31.5600	SPRABERRY	528	142	12,172	-	6	378	19,900	-	-	33,126	7.4
42250194	STERLING	-101.2500	31.5700	SPRABERRY	1,280	342	28,680	-	64	439	47,200	-	-	78,005	7.1
42250195	STERLING	-101.2500	31.5600	SPRABERRY	336	142	7,670	-	42	359	12,600	-	-	21,149	7.7
42250196	STERLING	-101.2500	31.5600	SPRABERRY	312	127	12,448	-	360	444	19,600	-	-	33,291	7.6
42250197	STERLING	-101.2500	31.5600	SPRABERRY	436	171	12,436	-	17	415	20,200	-	-	33,675	7.5
42250199	STERLING	-101.2500	31.5600	SPRABERRY	352	152	9,695	-	2	376	15,800	-	-	26,377	7.5
42250200	STERLING	-101.2600	31.5600	SPRABERRY	560	210	17,240	-	150	491	27,800	-	-	46,451	7.4
42250201	STERLING	-101.2600	31.5600	SPRABERRY	608	229	18,134	-	160	512	29,300	-	-	48,943	7.7
42250488	STERLING	-	-	SPRABERRY	448	174	12,933	-	3	425	21,000	-	-	34,983	7.8

Designation	Co.	LongDD	LatDD	Sample Interval	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	SO4 (mg/L)	HCO3 (mg/L)	Cl (mg/L)	Br (mg/L)	B (mg/L)	TDS (mg/L)	pH
42250489	STERLING	-	-	SPRABERRY	380	154	11,749	-	2	417	19,000	-	-	31,702	7.7
42250490	STERLING	-	-	SPRABERRY	664	213	16,815	-	4	398	27,500	-	-	45,594	7.4
42250491	STERLING	-	-	SPRABERRY	424	161	13,443	-	2	437	21,700	-	-	36,167	7.6
42250492	STERLING	-	-	SPRABERRY	396	159	11,057	-	7	371	18,000	-	-	29,990	7.4
42250494	STERLING	-	-	SPRABERRY	320	135	11,287	-	2	464	18,100	-	-	30,308	7.9
42250495	STERLING	-	-	SPRABERRY	400	127	10,530	-	5	373	17,100	-	-	28,535	7.6
42250497	STERLING	-	-	SPRABERRY	720	205	15,392	-	11	354	25,400	-	-	42,082	7.1
42250664	STERLING	-101.2500	31.5600	SPRABERRY	1,420	390	31,353	-	0	366	51,800	-	-	85,329	7.1
42002999	STERLING	-100.9800	31.6400	WICHITA ALBANY	3,187	813	37,064	-	1,914	188	63,638	-	-	106,804	6.9
42000394	STERLING	-101.1600	32.0400	WOLFCAMP	3,480	979	27,897	-	3,141	28	49,847	-	-	85,756	8.7
42001819	STERLING	-100.9100	32.0200	WOLFCAMP	3,394	510	11,716	-	1,251	60	24,601	-	-	41,533	5.8
42001852	STERLING	-101.1400	31.9900	WOLFCAMP	148	18	665	-	390	207	952	-	-	2,393	7.2
42002871	STERLING	-100.9800	31.6500	WOLFCAMP	4,321	649	16,166	-	863	197	33,712	-	-	55,907	7.0
42003000	STERLING	-100.9800	31.6400	WOLFCAMP	3,898	887	33,421	-	878	295	60,197	-	-	99,576	6.4
42007671	STERLING	-101.1600	32.0600	WOLFCAMP	12,227	736	21,772	-	974	165	56,535	-	-	92,410	6.0
42007672	STERLING	-101.1600	32.0600	WOLFCAMP	16,747	1,016	16,598	-	899	12	57,515	-	-	92,787	5.2
42007673	STERLING	-101.1600	32.0600	WOLFCAMP	3,600	849	26,702	-	450	195	49,572	-	-	81,368	6.3
42007674	STERLING	-101.1600	32.0600	WOLFCAMP	4,910	1,673	43,006	-	3,117	409	77,341	-	-	130,456	6.6
42007675	STERLING	-101.1600	32.0600	WOLFCAMP	9,226	499	29,195	-	1,862	934	60,882	-	-	102,597	7.2
42007676	STERLING	-101.1600	32.0600	WOLFCAMP	10,028	456	28,317	-	2,807	985	60,802	-	-	102,438	7.2
42015627	STERLING	-	-	WOLFCAMP	241	56	1,857	-	955	932	2,211	-	-	6,252	6.9
42015628	STERLING	-	-	WOLFCAMP	156	51	2,629	-	890	659	3,440	-	-	7,825	-
42015629	STERLING	-	-	WOLFCAMP	190	37	4,850	-	899	974	6,696	-	-	13,646	7.4
SSR*	TOM GREEN	-100.2330	31.5830	CANYON	9,600	1,400	59,000	230.0	180	-	37,000	90	3.20	-	-
Veribest*	TOM GREEN	-100.2340	31.4680	STRAWN	6,500	1,100	37,000	360.0	1,100	-	59,000	330	6.30	-	-
**	TOM GREEN	-100.2340	31.4680	STRAWN	13,110	1,830	43,820	250.0	53	20	90,740	360	-	-	6.3
**	TOM GREEN	-100.2330	31.5830	CANYON	9,560	1,530	40,840	450.0	660	81	78,960	280	-	-	6.9
**	TOM GREEN	-100.3990	31.6540	CANYON	9,970	1,970	40,560	1,050.0	760	145	81,470	200	-	-	6.5
**	TOM GREEN	-100.6250	31.6380	STRAWN	13,970	2,960	62,400	545.0	19	73	119,850	460	-	-	5.8
**	TOM GREEN	-100.5950	31.5880	LEO-BLAINE	921	491	7,185	86.0	2,070	250	11,630	10	-	-	7.9
**	TOM GREEN	-100.2500	31.3020	STRAWN	8,230	1,510	38,180	593.0	950	204	74,250	230	-	-	6.2
**	TOM GREEN	-100.2830	31.4170	COM. PEAK	1,730	1,050	4,910	57.0	905	265	13,070	22	-	-	6.9
**	TOM GREEN	-100.4260	31.3360	COLEMAN JCT	1,720	950	16,960	320.0	4,310	250	29,610	33	-	-	7.6
**	TOM GREEN	-100.4260	31.3360	COLEMAN JCT	1,290	540	11,240	155.0	3,130	435	19,380	40	-	-	7.5
**	TOM GREEN	-100.4840	31.4290	SAN ANGELO	1,890	760	19,730	270.0	3,695	500	33,140	61	-	-	7.1
**	TOM GREEN	-100.5540	31.4650	CANYON	9,530	1,610	43,940	445.0	540	116	86,150	350	-	-	6.8
**	TOM GREEN	-100.5080	31.4910	-	2,400	881	25,100	349.0	3,920	412	41,200	83	-	-	7.7
**	TOM GREEN	100.6490	31.5660	STRAWN	13,040	1,640	55,590	320.0	24	132	113,140	450	-	-	6.5
**	TOM GREEN	-100.7120	31.5970	STRAWN	10,150	1,680	53,660	397.0	10	212	102,840	410	-	-	6.6
**	TOM GREEN	-100.7280	31.5990	SAN ANDRES	2,410	1,330	28,930	488.0	3,220	612	48,510	61	-	-	6.8
**	TOM GREEN	-100.8560	31.6330	CLEAR FORK	2,240	822	29,750	445.0	3,490	797	47,680	73	-	-	6.6
**	TOM GREEN	-100.8570	31.6450	SAN ANDRES	1,980	867	32,620	399.0	1,860	297	52,620	67	-	-	7.6
**	TOM GREEN	-100.6080	31.3610	LEONA	1,465	430	11,540	165.0	645	555	20,750	35	-	-	6.7
**	TOM GREEN	-100.6000	31.3600	LEONA	750	270	6,920	175.0	520	365	12,190	15	-	-	7.2
**	TOM GREEN	-100.6830	31.2110	SAN ANGELO	931	696	15,600	213.0	9	548	27,200	57	-	-	7.3
**	TOM GREEN	-100.5040	31.1140	STRAWN	2,980	682	29,180	741.0	1,240	362	49,520	50	-	-	7.1

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